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### **1.0 SCOPE AND DEFINITION**

The FTIHWG cost-benefit analysis includes the large, medium, and small airplane categories. The regional turboprop, regional turboprop, and business jet categories were excluded because they would have had just a small impact on the overall safety benefit, and including their costs would have significantly and disproportionately increased the cost-benefit ratio.

For each of the fuel tank inerting systems described in this report, the total cost is given over the 16-year study period (2005 through 2020). This total cost includes the initial airplane and airport modification costs plus the accumulated annual recurring costs. Airplane nonrecurring costs include engineering design for the modifications and additions to fuel system components, interfaces, instruments or displays, relocation of other equipment, wiring, tubing or ducting, and avionics software or modules. The nonrecurring engineering costs also include changes to documents (e.g., Specs, ICDs); manuals (e.g., AFM, Opts, MM); production change records; laboratory, ground, and flight tests; and FAA/JAA certification. These costs also include major-supplier parts and assemblies, tubing, wiring, ducting, Service Bulletin and kitting costs (retrofit), and special tooling for installation.

For airlines, costs include engineering and training costs, installation labor, and airplane downtime. The airplane downtime cost estimates were based on the cost to lease a comparable airplane during the retrofit period. It was assumed that 80% of the airplanes would be retrofitted during a major check and 20% were retrofitted outside of the major check cycle. For the large-airplane category, the estimated downtime was 9 days for retrofitting during a major check, and 11 days for retrofitting outside of a major check. A medium-category airplane was assumed to take 8 days during a major check and 10 days outside of a major check. For the small-category airplane, the retrofit was assumed to take 7 days during a major check and 9 days outside of a major check.

Airplane annual recurring costs include training, maintenance checks, inspections, removals, unscheduled maintenance, airplane delays. The annual weight penalty per 1,000 lb is \$165,532 for a large airplane, \$131,802 for a medium airplane, and \$62,004 for a small airplane. The cost of the weight penalty was based on values from the 1998 ARAC study.

The ground-based inerting (GBI) system costs include the costs for a fixed hydrant system and a mobile truck-based system for large- and medium-size airports. Small and foreign airports have only a mobile system. The nonrecurring airport costs include engineering design, system installation labor (including relocation of other equipment), parts and materials, and tooling. The annual recurring costs include the cost of the N<sub>2</sub> required for ullage washing, the ground service labor for inerting, and N<sub>2</sub> system maintenance, inspection, and training.

For the onboard ground inerting systems (OBGI), the airport costs included the additional ground support equipment for providing required electrical power at large and medium-sized airports. It was assumed that the airplane's APU would be used at small airports. It was assumed that the Onboard Inert Gas Generating System (OBIGGS) required no ground support equipment.

The overall airplane and airport costs for each system was calculated by multiplying the recurring and nonrecurring airplane costs by the appropriate number of airplanes. It was assumed that all airplanes built after 2007 would have the inerting system installed and that airplanes built before 2007 would require a retrofit. The airport costs were calculated by multiplying the number of large, medium, and small airports by their respective recurring and nonrecurring costs. For the US-only implementation cases, it was assumed that all B, C, and D category airports in the United States would be modified and that 158 foreign airports that are currently serviced by US operators would also be modified.

For several reasons, the airport costs estimated in this study are higher than the values listed in the FAA report DOT/FAA/AR-00/19, "The Cost of Implementing Ground Based Fuel Tank Inerting in the Commercial Fleet," dated May 2000. The FAA study only estimated the airport costs; no airplane costs were included. The FAA estimated that the airport cost of a US ground-based system for inerting heated

center wing tanks would be \$800 million US over a 10-year period starting in 2003. In contrast, this FTIHWG study estimates that the airport recurring and nonrecurring costs would be approximately \$6.8 billion US over a 16-year period.

The primary reasons for this difference in anticipated costs between the above-referenced FAA study and the ARAC study presented here is that the FTIHWG:

- Used a study period 60 percent longer than the FAA's because of the long time required to fully implement fuel tank inerting.
- Assumed higher nonrecurring airport cost primarily because it factors in higher equipment costs required to support remote airplane parking at large and medium airports.
- Included more airports in its study—whereas the FAA assumes 50 large airports and 350 small airports, this study assumes 31 large airports, 37 medium airports, and 354 small airports as well as 158 foreign airports served by US operators.
- Assumed a burdened-labor rate of \$25 per hour for ground service workers, which is nearly twice the burdened-labor rate assumed by the FAA study.
- Assumed ground-servicing hours two to three times higher, depending on airplane model, based on an underlying assumption that the worker would not leave the airplane hook-up unattended while the fuel tank was being serviced with nitrogen.
- Assumed that each airplane model would be serviced with the same amount of nitrogen, regardless of fuel load, thus requiring significantly more total nitrogen.
- Projects a 30% rise in the cost of nitrogen (from \$0.10 per 100 cubic feet to \$0.13 per 100 cubic feet) as forecast by an industrial gas company.
- Assumed 3% annual inflation in the cost of parts and labor.

The benefit values presented in this report are based on the assumption that 85% of fuel-tank-related accidents would occur in the air and the remaining 15% on the ground. Also included were the benefits of enhanced occupant survival in airplane accidents resulting from other causes, in which inerting could potentially prevent a post-crash fuel tank fire or explosion. Benefit values in this document do not reflect the confined-space hazard that wide-scale adoption of fuel tank inerting would introduce in the commercial fleet and in related ground-support areas. See section 4 for more information about benefits.

## **2.0 COST-BENEFIT ANALYSIS SUMMARY**

The following charts include the list of scenarios evaluated, the airplane and airport forecasts, standard airplane model data, accident cost data, and the cost-benefit summaries for each scenario. Note that scenarios 6, 8, and 10 have been combined with 5, 7 and 9 respectively.

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### Inerting Scenario Summary Information

Below are all of the scenario's address in the model. Note #6, 8, and 10 have been combined with 5,7, and 9.  
Small Transports, PSA/Membrane Systems have been added to 13-15 to have equal coverage as the other scenario's.

Scenario	Benefits used for Small
1 On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	
2 On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	
3 Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems	
4 Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems	
5 OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	From 6
<del>6 OBIGGS, All Tanks, Small Transports, PSA and Membrane Systems</del>	
7 Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	From 8
<del>8 Hybrid OBIGGS, HCWT only, Small Transports, PSA and Membrane Systems</del>	
9 Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems	From 10
<del>10 Hybrid OBIGGS, All Tanks, Small Transports, PSA and Membrane Systems</del>	
11 Ground Based Inerting HCWT only, All Transports	
12 Ground Based Inerting All Fuselage Tanks, All Transports	
13 OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems	From 6
14 Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems	From 8
15 Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems	From 10
16 On-Board Liquid Nitrogen Inerting	

All Scenario dollars are in Year 2000 US\$'s

The Airplane Non-Recurring costs are divided into First-of-a-model and derivative model costs. The

First-of-a-Model costs are for the design, analysis and certification for the first of an airplane type

The derivative Model costs are for the subsequent airplanes of that type.

The Recurring Airplane costs are on an annual per-airplane basis

The Airport costs based on Large, Medium or Small airports plus 4 or 2 truck Mobile unit for foreign airports if the model is US only

*Figure G-1. Scenario Information Sheet*

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Note: Actual value of the Fleet were adjusted for each scenario based on the appropriate tank mix.

Active Scenario:			Tank Mix Values for Active Scenario										Tank Mix ON/OFF(1/0): 1											
Scenario 16 - On-Board Liquid Nitrogen Inerting			In-Service				New				As provided by Alan B Hedge[SMTP:ahedge@air-econ.com] The Campbell-Hill Aviation Group, Inc.													
			Large	Medium	Small	Regional Jet	Large	Medium	Small	Regional Jet														
			100%	100%	100%	0%	100%	100%	100%	0%														
			ARAC Distribution 50-99 (Regional + Biz Jet) 100-210 (Small) (211-400)/2 (Medium) 400-600+ (211-400)/2 (Large)																					
Operator	World																							
			Data																					
Mission	Type	Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Pax	Retain	xRegional Jet	1381	1383	1310	1325	1330	1349	1357	1363	1356	1348	1339	1333	1323	1317	1294	1299	1290	1280	1271	1244	1229	
		Small Transport	7506	7515	7314	7353	7406	7453	7441	7423	7393	7360	7323	7275	7242	7214	7157	7119	7082	7054	7004	6963	6930	
		Medium Transport	1088	1085	1084.5	1082	1080	1078.5	1074.5	1068.5	1065	1061.5	1055.5	1048	1039.5	1031.5	1027.5	1020.5	1010.5	996.5	981	967.5	952.5	
		Large Transport	1619	1617	1615.5	1614	1612	1609.5	1596.5	1582.5	1565	1551.5	1516.5	1466	1439.5	1419.5	1402.5	1388.5	1368.5	1351.5	1324	1301.5	1283.5	
	New	xRegional Jet	190	361	579	678	703	730	763	800	864	935	1001	1071	1143	1214	1304	1377	1467	1570	1662	1792	1918	
		Small Transport	389	865	1486	1824	2009	2220	2513	2858	3239	3674	4103	4610	5089	5576	6134	6656	7228	7792	8406	9031	9669	
		Medium Transport	61.5	126	182	241	282	327.5	383	439.5	502	565.5	642	728.5	814	885.5	966	1060	1156	1249	1357	1464	1582.5	
		Large Transport	68.5	152	232	321	389	460.5	553	648.5	757	864.5	1001	1162.5	1304	1428.5	1559	1706	1859	2004	2172	2339	2516.5	
Freighter	Retain	xRegional Jet	43	43	40	40	40	40	40	42	42	42	42	42	42	42	42	43	43	43	43	43	43	
		Small Transport	798	796	702	705	711	706	717	726	727	729	726	714	703	687	676	665	658	648	639	628	621	
		Medium Transport	306.5	316.5	312	314.5	318.5	319	320	324.5	324.5	326	326.5	326	326	326.5	327	328	327.5	326.5	325.5	324.5	323.5	
		Large Transport	344.5	354.5	350	352.5	356.5	357	359	364.5	366.5	369	371.5	373	377	378.5	382	386	388.5	390.5	391.5	387.5	390.5	
	New	xRegional Jet	0	1	9	11	14	19	22	25	30	34	38	43	49	55	60	68	74	80	90	97	106	
		Small Transport	0	32	159	204	250	300	360	437	511	567	635	711	781	866	972	1076	1200	1310	1419	1521	1643	
		Medium Transport	4.5	12	33.5	54.5	73.5	90	111.5	141.5	164.5	193	220.5	250.5	277	313	353.5	397	435	481.5	525.5	574.5	631.5	
		Large Transport	13.5	27	52.5	75.5	97.5	114	137.5	170.5	196.5	227	255.5	286.5	317	354	396.5	447	486	535.5	585.5	642.5	704.5	
Grand Total			13813	14686	15461	16195	16672	17173	17748	18414	19103	19847	20596	21440	22266	23108	24053	25036	26073	27112	28196	29320	30544	

Figure G-2. Airplane Forecast—World Fleet

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Note: Actual value of the Fleet were adjusted for each scenario based on the appropriate tank mix.

Active Scenario:			Tank Mix Values for Active Scenario										Tank Mix ON/OFF(1/0): 1											
Scenario 16 - On-Board Liquid Nitrogen Inerting			In-Service				New				As provided by Alan B Hedge[SMTP:ahedge@air-econ.com] The Campbell-Hill Aviation Group, Inc.													
			Large	Medium	Small	Regional Jet	Large	Medium	Small	Regional Jet														
			100%	100%	100%	0%	100%	100%	100%	0%														
			ARAC Distribution 50-99 (Regional + Biz Jet) 100-210 (Small) (211-400)/2 (Medium) 400-600+ (211-400)/2 (Large)																					
Operator	World - PAX Only ▾																							
			Data																					
Mission	Type	Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Pax	Retain	xRegional Jet	1381	1383	1310	1325	1330	1349	1357	1363	1356	1348	1339	1333	1323	1317	1294	1299	1290	1280	1271	1244	1229	
		Small Transport	7506	7515	7314	7353	7406	7453	7441	7423	7393	7360	7323	7275	7242	7214	7157	7119	7082	7054	7004	6963	6930	
		Medium Transport	1088	1085	1084.5	1082	1080	1078.5	1074.5	1068.5	1065	1061.5	1055.5	1048	1039.5	1031.5	1027.5	1020.5	1010.5	996.5	981	967.5	952.5	
		Large Transport	1619	1617	1615.5	1614	1612	1609.5	1596.5	1582.5	1565	1551.5	1516.5	1466	1439.5	1419.5	1402.5	1388.5	1368.5	1351.5	1324	1301.5	1283.5	
	New	xRegional Jet	190	361	579	678	703	730	763	800	864	935	1001	1071	1143	1214	1304	1377	1467	1570	1662	1792	1918	
		Small Transport	389	865	1486	1824	2009	2220	2513	2858	3239	3674	4103	4610	5089	5576	6134	6656	7228	7792	8406	9031	9669	
		Medium Transport	61.5	126	182	241	282	327.5	383	439.5	502	565.5	642	728.5	814	885.5	966	1060	1156	1249	1357	1464	1582.5	
		Large Transport	68.5	152	232	321	389	460.5	553	648.5	757	864.5	1001	1162.5	1304	1428.5	1559	1706	1859	2004	2172	2339	2516.5	
Freighter	Retain	xRegional Jet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Small Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Medium Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Large Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	New	xRegional Jet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Small Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Medium Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Large Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Grand Total			12303	13104	13803	14438	14811	15228	15681	16183	16741	17360	17981	18694	19394	20086	20844	21626	22461	23297	24177	25102	26081	

Figure G-3. Airplane Forecast—World Fleet, Passenger Only

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Note: Actual value of the Fleet were adjusted for each scenario based on the appropriate tank mix.

Active Scenario:			Tank Mix Values for Active Scenario										Tank Mix ON/OFF(1/0): 1											
Scenario 16 - On-Board Liquid Nitrogen Inerting			In-Service				New				As provided by Alan B Hedge[SMTP:ahedge@air-econ.com] The Campbell-Hill Aviation Group, Inc.													
			Large	Medium	Small	Regional Jet	Large	Medium	Small	Regional Jet														
			100%	100%	100%	0%	100%	100%	100%	0%														
			ARAC Distribution 50-99 (Regional + Biz Jet) 100-210 (Small) (211-400)/2 (Medium) 400-600+ (211-400)/2 (Large)																					
Operator	US-Operator																							

Figure G-4. Airplane Forecast—U.S. Fleet

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Note: Actual value of the Fleet were adjusted for each scenario based on the appropriate tank mix.

Active Scenario:			Tank Mix Values for Active Scenario										Tank Mix ON/OFF(1/0): 1											
Scenario 16 - On-Board Liquid Nitrogen Inerting			In-Service				New				As provided by Alan B Hedge[SMTP:ahedge@air-econ.com] The Campbell-Hill Aviation Group, Inc.													
			Large	Medium	Small	Regional Jet	Large	Medium	Small	Regional Jet														
			100%	100%	100%	0%	100%	100%	100%	0%														
			ARAC Distribution 50-99 (Regional + Biz Jet) 100-210 (Small) (211-400)/2 (Medium) 400-600+ (211-400)/2 (Large)																					
Operator	US-Operator - PAX (▼)																							
			Data																					
Mission	Type	Category	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Pax	Retain	xRegional Jet	527	525	509	511	510	509	509	508	508	507	507	504	482	446	389	389	383	378	378	365	353	
		Small Transport	3384	3380	3315	3297	3280	3267	3255	3247	3234	3220	3210	3194	3178	3172	3153	3130	3100	3098	3084	3088	3095	
		Medium Transport	265	263.5	261.5	262	262.5	263.5	264	264.5	265.5	265.5	262	260.5	261.5	263	265	265	264.5	266	267	267.5	267.5	
		Large Transport	322	321.5	319.5	321	321.5	323.5	325	326.5	327.5	328.5	326	325.5	327.5	330	333	334	334.5	337	339	341.5	342.5	
	New	xRegional Jet	111	218	325	358	360	362	369	380	389	401	415	430	444	486	532	550	578	611	635	680	720	
		Small Transport	181	408	687	839	891	954	1053	1180	1320	1482	1645	1817	1996	2172	2371	2575	2791	2992	3209	3419	3623	
		Medium Transport	28.5	49	59	66.5	73	78.5	89.5	97	105.5	115	128.5	144.5	155.5	167	179	195	211.5	223.5	239.5	253.5	271	
		Large Transport	29.5	50	60	67.5	74	79.5	90.5	98	106.5	116	129.5	145.5	156.5	168	180	196	212.5	224.5	240.5	254.5	272	
Freighter	Retain	xRegional Jet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Small Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Medium Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Large Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	New	xRegional Jet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Small Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Medium Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
		Large Transport	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Grand Total			4848	5215	5536	5722	5772	5837	5955	6101	6256	6435	6623	6821	7001	7204	7402	7634	7875	8130	8392	8669	8944	

Figure G-5. Airplane Forecast—U.S. Fleet, Passenger Only

## Estimating and Forecasting Task Team Final Report

Airport Data for Inerting Support													
<i>Note: Driven by Fleet Control Page</i>													
Operator:	World	US Data Provided from FAA Data and input from Steve Henderson - Boeing, World data from Ed Gervais - Boeing, based on Airport serviced											
	US Only Airports	World Airport	Current Airport Data										
Large Airport	31	85	85										
Medium Airport	37	101	101										
Small Airport	354	1014	1014										
Non US - 4 Truck Support	83		0										
Non US - 2 Truck Support	75		0										
Cum Conversion %:	14%	29%	43%	57%	71%	86%	100%	100%	100%	100%	100%	100%	100%
<b>Cum Converted Airports</b>													
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Large Airport	12	24	36	49	61	73	85	85	85	85	85	85	85
Medium Airport	14	29	43	58	72	87	101	101	101	101	101	101	101
Small Airport	145	290	435	579	724	869	1,014	1,014	1,014	1,014	1,014	1,014	1,014
Non US - 4 Truck Support	-	-	-	-	-	-	-	-	-	-	-	-	-
Non US - 2 Truck Support	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Annual Airport Conversion</b>													
Large Airport	12	12	12	12	12	12	12	-	-	-	-	-	-
Medium Airport	14	14	14	14	14	14	14	-	-	-	-	-	-
Small Airport	145	145	145	145	145	145	145	-	-	-	-	-	-
Non US - 4 Truck Support	-	-	-	-	-	-	-	-	-	-	-	-	-
Non US - 2 Truck Support	-	-	-	-	-	-	-	-	-	-	-	-	-

Figure G-6. Airport Forecast—World and United States

## Estimating and Forecasting Task Team Final Report

Provided by: <i>Allen Mattes</i> [SMTP: <i>Allen.Mattes@faa.gov</i> ]											
	AIRPLANE CATEGORY	LOAD FACTORS									
	>300	75.00%									
	210-300	73.00%									
	100-209	71.00%									
	REGIONAL JET	60.00%									
	TURBOPROP	60.00%									
	BIZJET	40.00%									
	VALUE OF A FATALITY	\$2.70									
	FATALITY RATE IN-FLIGHT	100.00%									
	FATALITY RATE ON-THE GROUND	10.00%									
LOSSES FROM AN IN-FLIGHT EXPLOSION											
	AIRPLANE CATEGORY		AVG. A/C SIZE	AVG. NUM. PAX	AVG. NUM. CREW	AVG.NUM. FATALITIES	OF PAX	VALUE OF A/C	VALUE OF GROUND DAMAGE	COST OF ACCIDENT INVESTIGATION	TOTAL COST OF ACCIDENT
	>300		350.00	263	12	275	\$741.15	\$75.00	\$5.00	\$33.00	\$854.15
	210-300		255.00	186	9	195	\$526.91	\$60.00	\$4.00	\$28.00	\$618.91
	100-209		154.50	110	7	117	\$315.08	\$25.00	\$3.00	\$23.00	\$366.08
	REGIONAL JET		65.00	39	5	44	\$118.80	\$17.00	\$3.00	\$20.00	\$158.80
	TURBOPROP		45.00	27	4	31	\$83.70	\$9.00	\$2.00	\$15.00	\$109.70
	BIZJET		11.00	4	3	7	\$19.98	\$7.00	\$1.00	\$10.00	\$37.98
LOSSES FROM AN ON-THE-GROUND EXPLOSION											
	AIRPLANE CATEGORY		AVG. A/C SIZE	AVG. NUM. PAX	AVG. NUM. CREW	AVG.NUM. FATALITIES	VALUE OF PAX	VALUE OF A/C	VALUE OF GROUND DAMAGE	COST OF ACCIDENT INVESTIGATION	TOTAL COST OF ACCIDENT
	>300		350.00	263	12	27	\$74.12	\$75.00	\$0.50	\$10.00	\$159.62
	210-300		255.00	186	9	20	\$52.69	\$60.00	\$0.40	\$8.00	\$121.09
	100-209		154.50	110	7	12	\$31.51	\$25.00	\$0.30	\$6.00	\$62.81
	REGIONAL JET		65.00	39	5	4	\$11.88	\$17.00	\$0.20	\$4.00	\$33.08
	TURBOPROP		45.00	27	4	3	\$8.37	\$9.00	\$0.10	\$3.00	\$20.47
	BIZJET		11.00	4	3	1	\$2.00	\$7.00	\$0.10	\$2.00	\$11.10

Figure G-7. Accident Cost Data

Summary of Inerting Scenario Results

World

Values in Millions

	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 2 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 6 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 8 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 10 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 11 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 12 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting
Total \$ Cost with Inflation	25,321	41,901	24,415	38,349	47,601	21,476	32,969	22,973	26,203	57,021	34,569	45,797	77,735	-	-	-
NPV in 2005 of Cost	11,592	18,509	11,240	17,035	20,775	9,896	14,936	10,374	11,885	24,605	15,440	20,405	31,527	-	-	-
Total Benefits	597	1,037	591	1,032	1,202	701	1,186	668	1,109	1,202	701	1,186	1,202	-	-	-
NPV in 2005 of Benefits	219	381	217	379	441	257	435	245	407	441	257	435	441	-	-	-

Figure G-8. Cost Summary of World Fleet

**Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

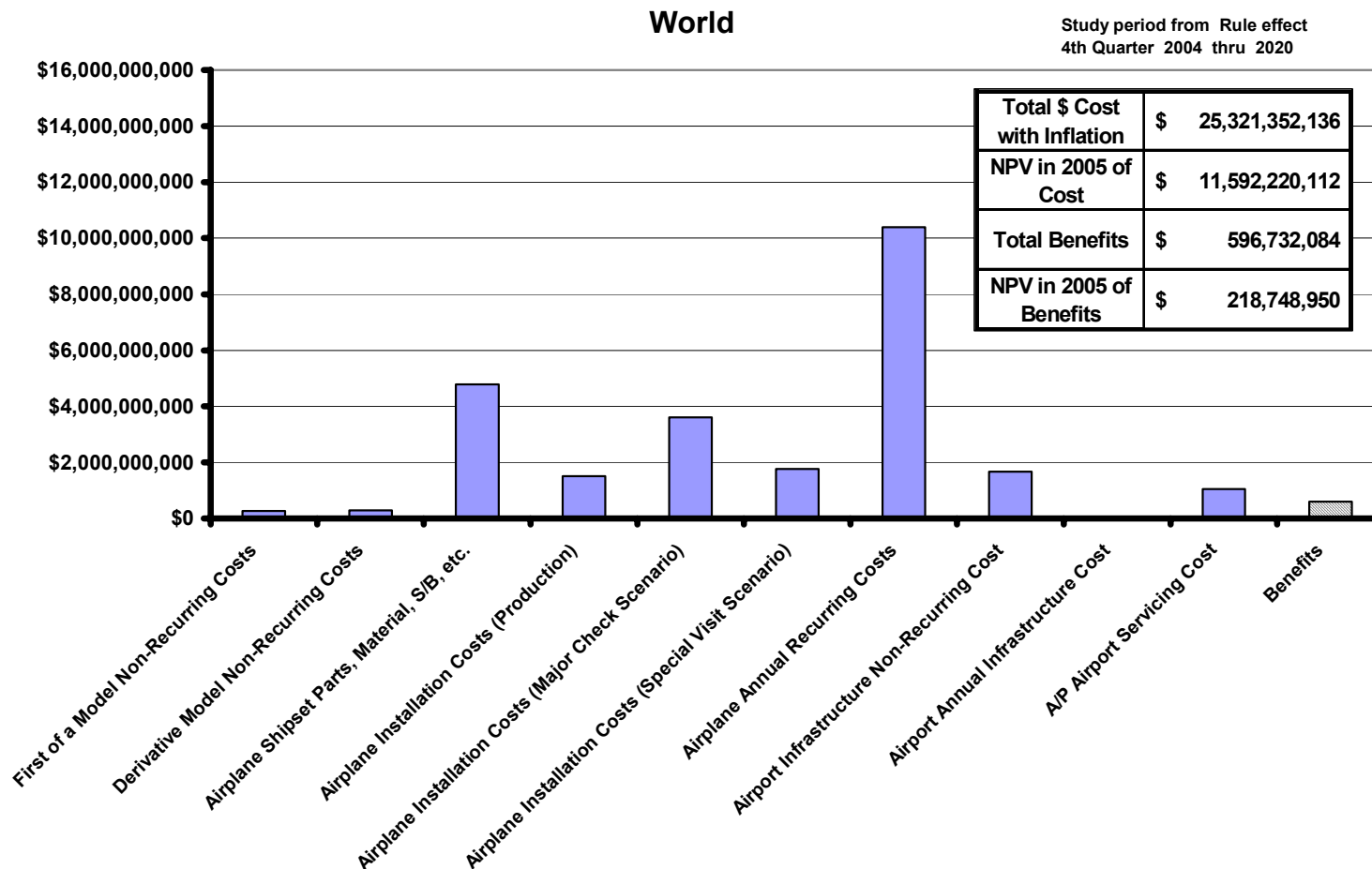


Figure G-9. Scenario 1—Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (World)

**Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

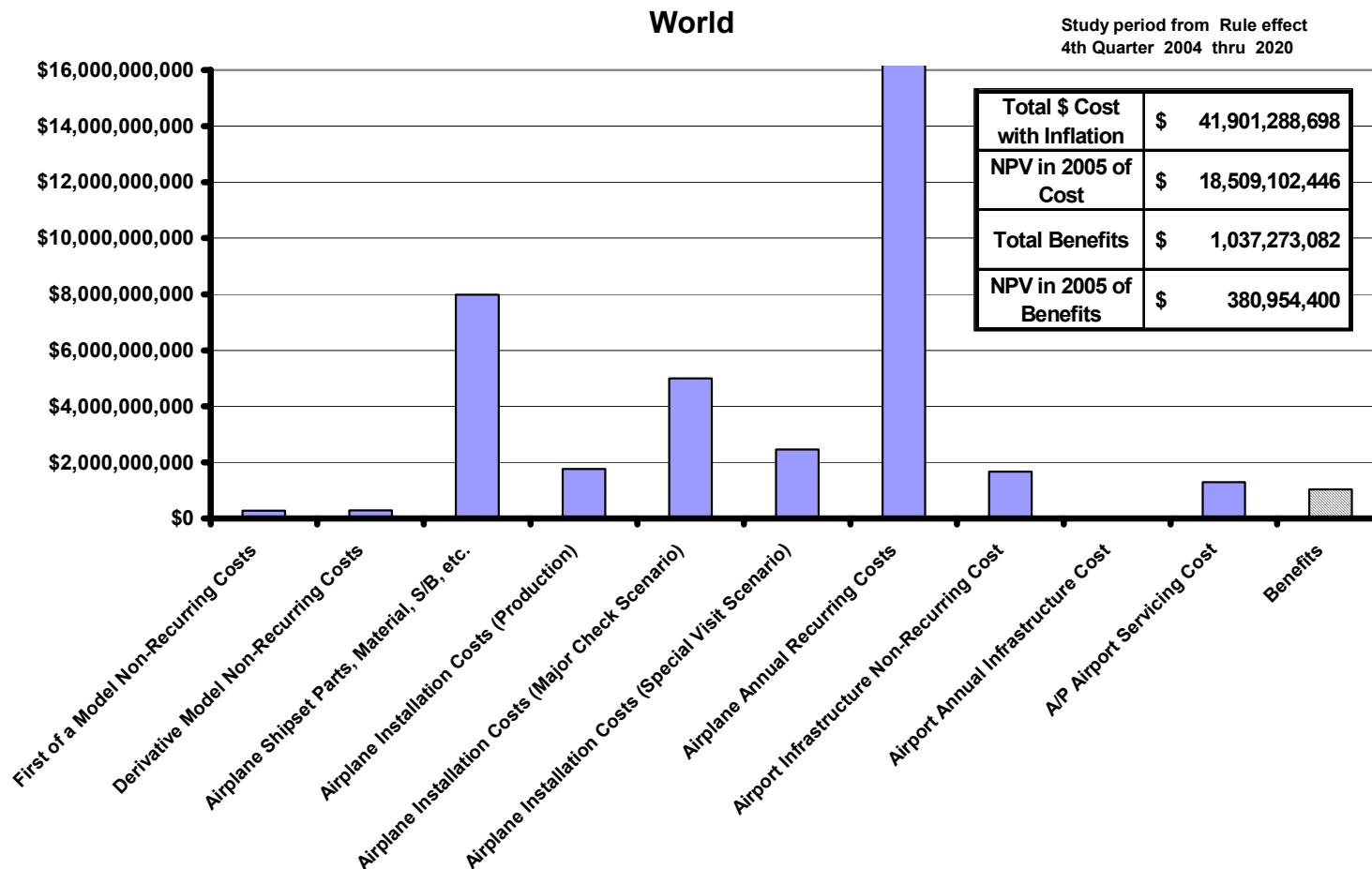


Figure G-10. Scenario 2—Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (World)

**Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

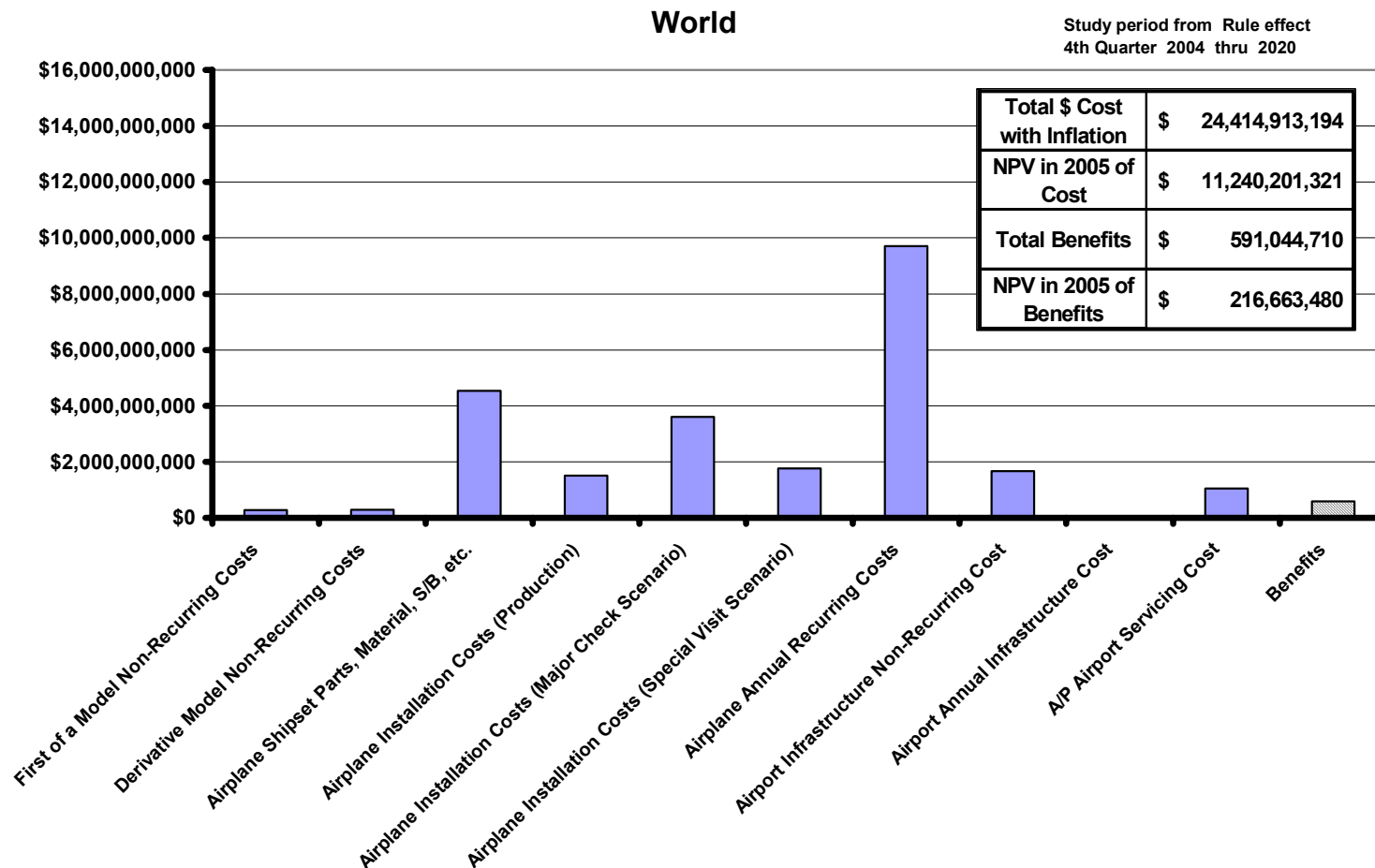


Figure G-11. Scenario 3—Hybrid Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (World)

**Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

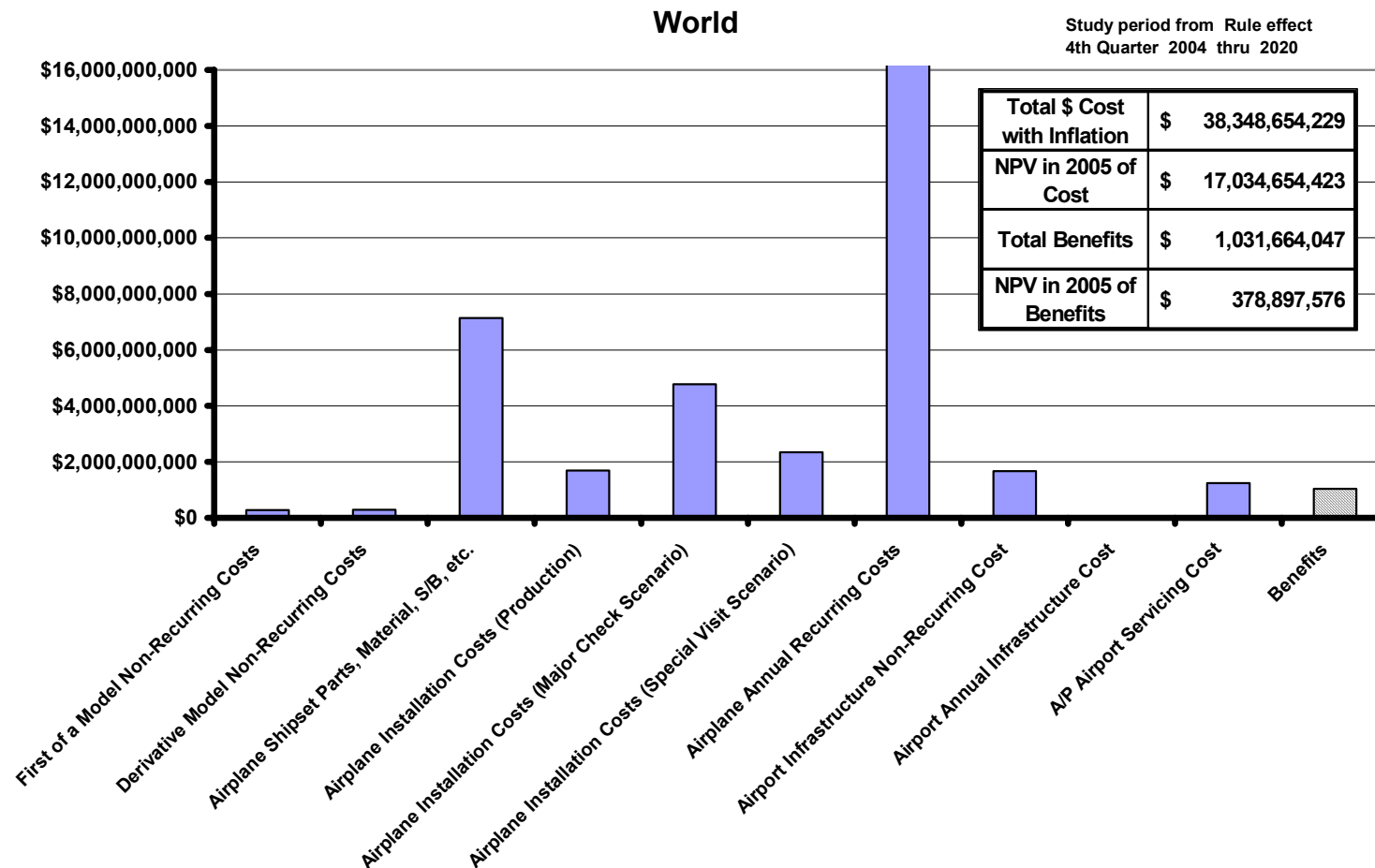


Figure G-12. Scenario 4—Hybrid Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (World)

**Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

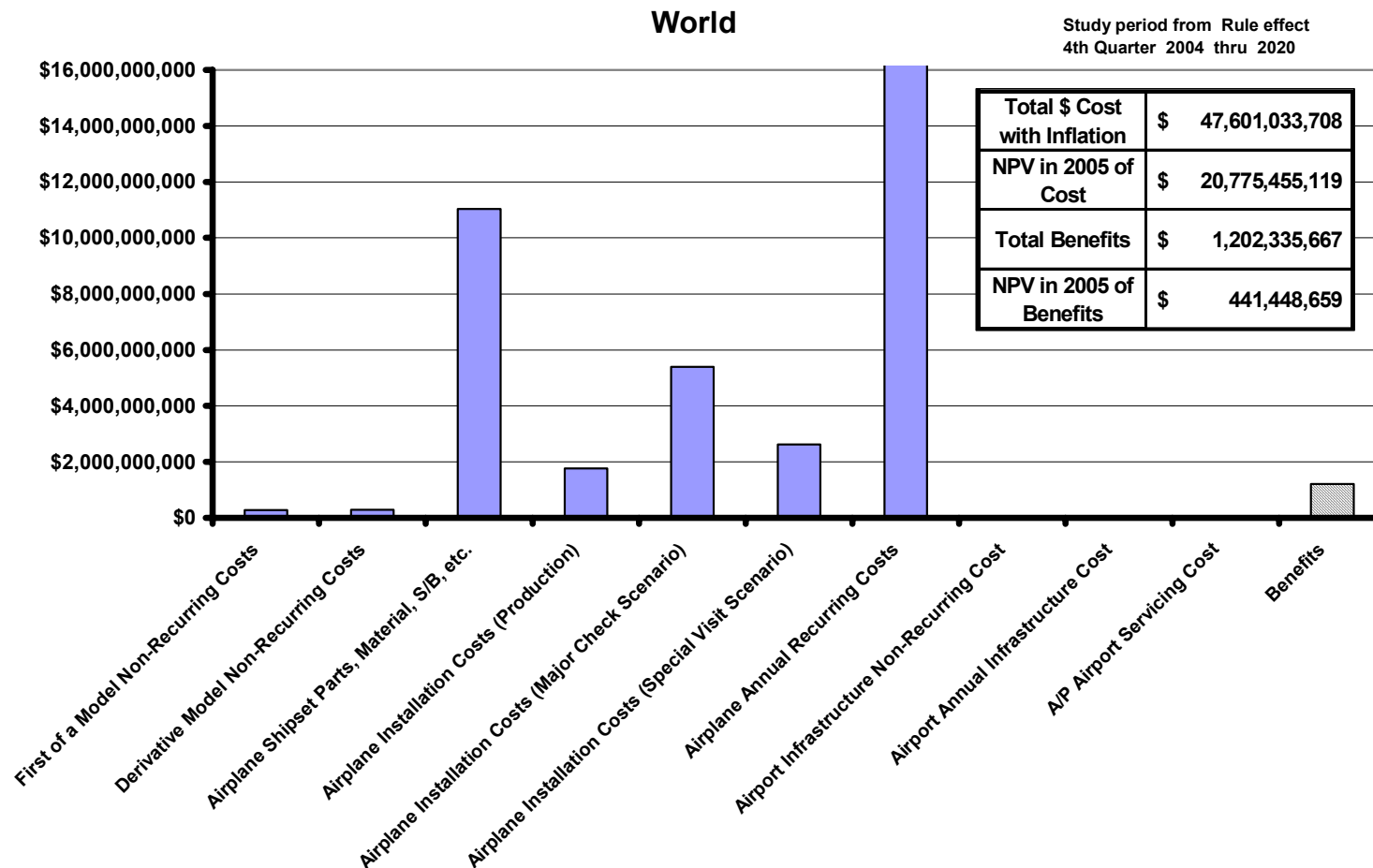


Figure G-13. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World)

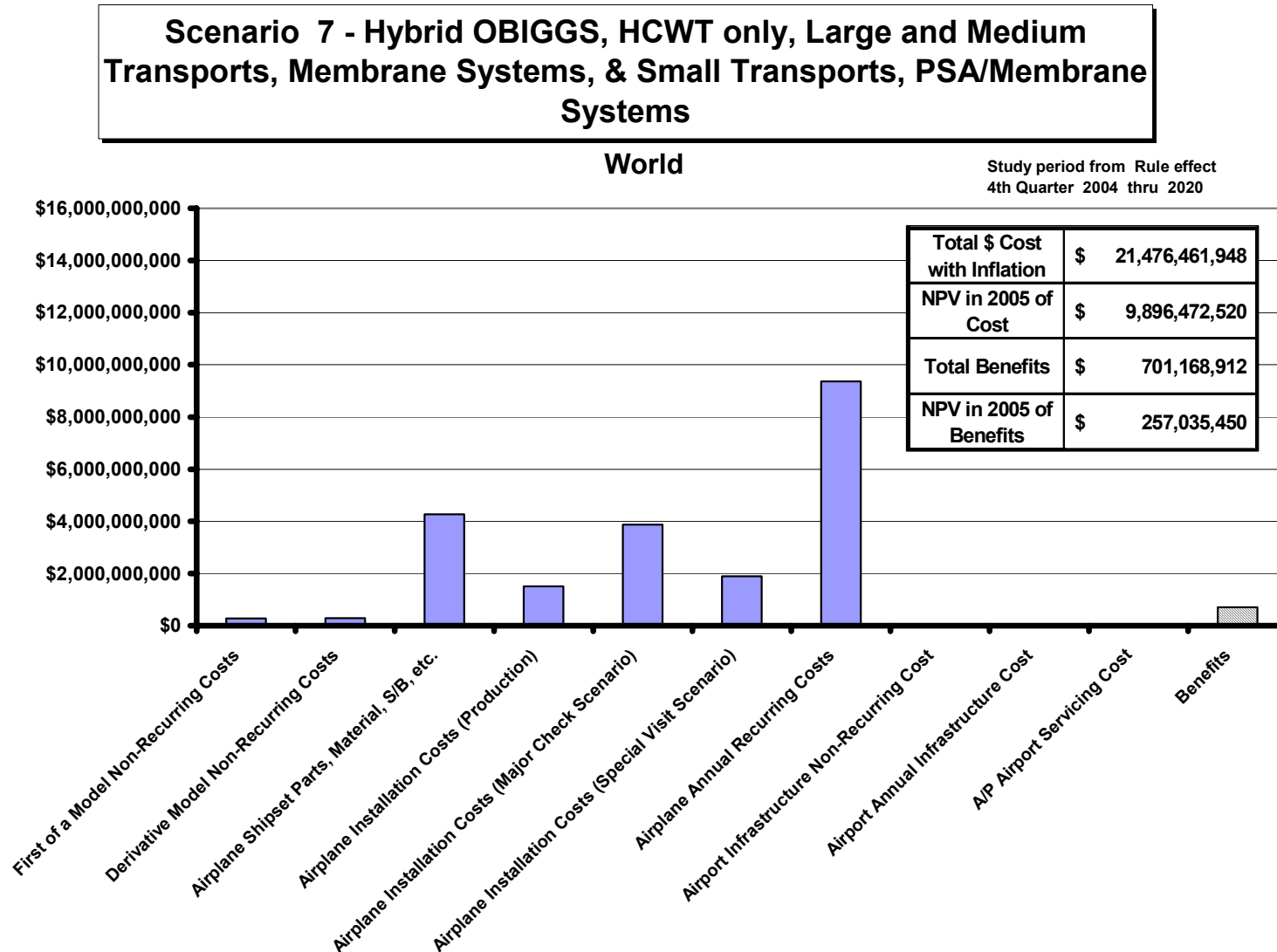


Figure G-14. Scenario 7—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World)

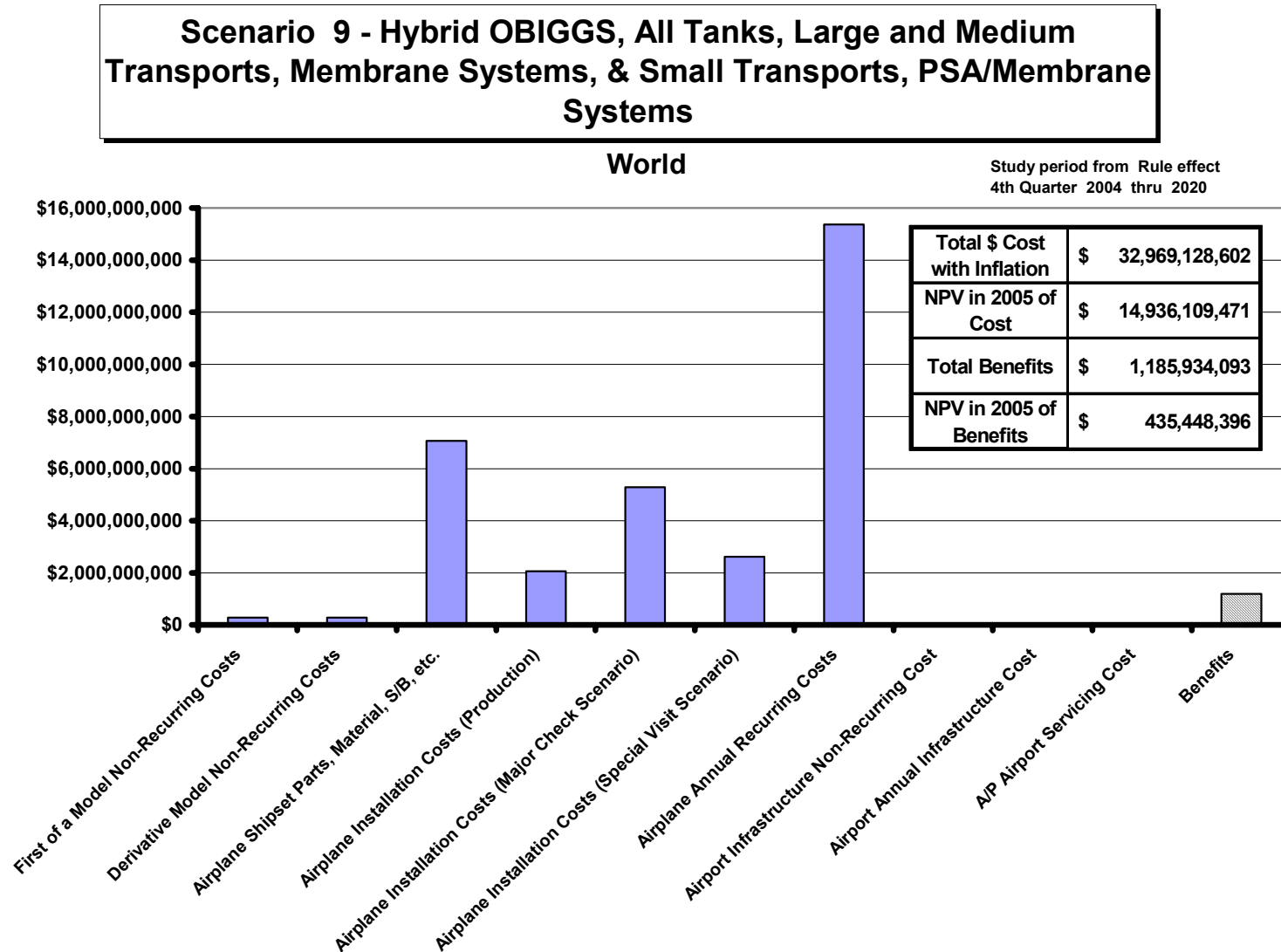


Figure G-15. Scenario 9—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World)

**Scenario 11 - Ground Based Inerting HCWT only, All Transports**

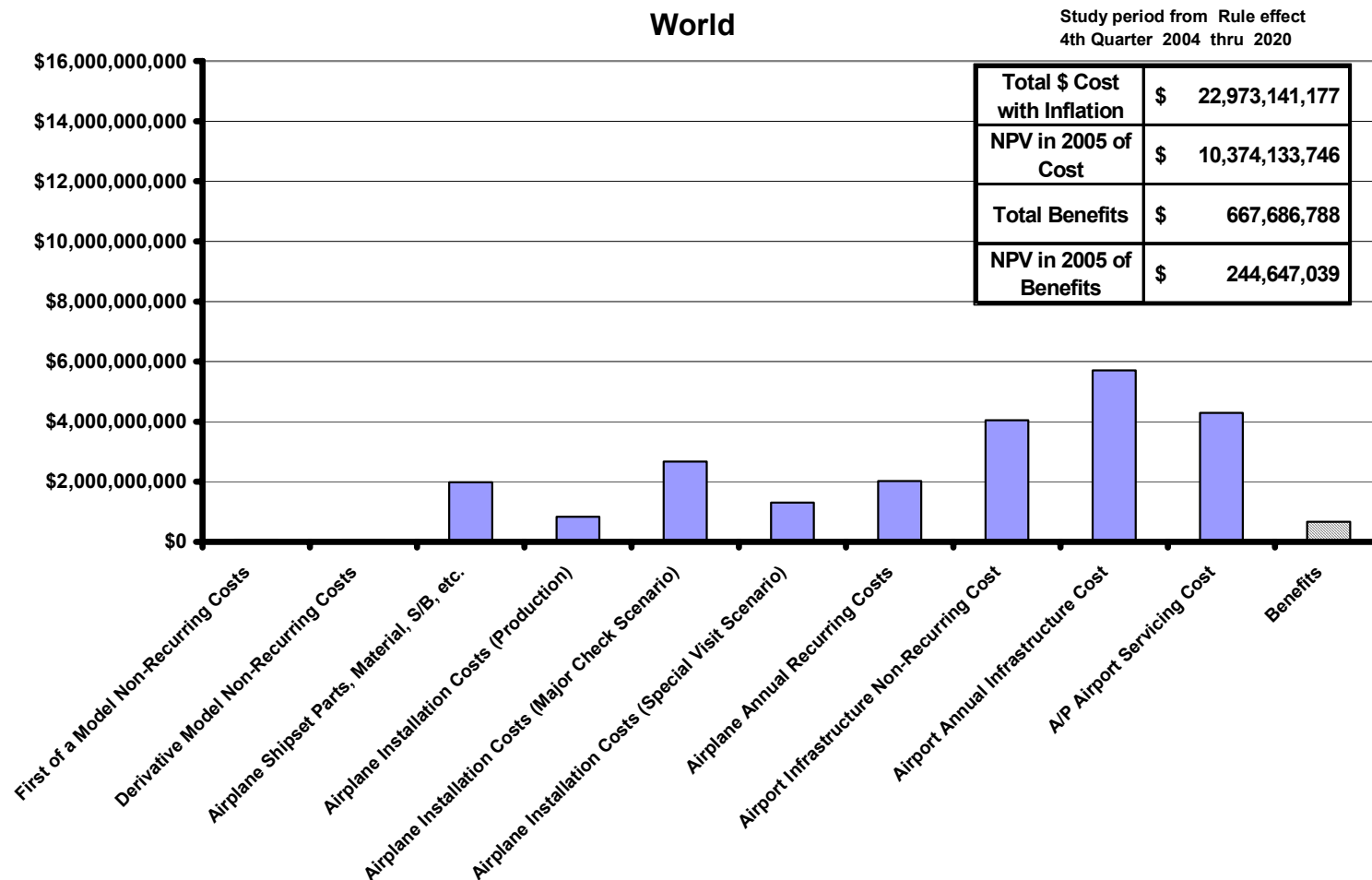


Figure G-16. Scenario 11—Ground-Based Inerting, HCWT Only, All Transports (World)

## Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports

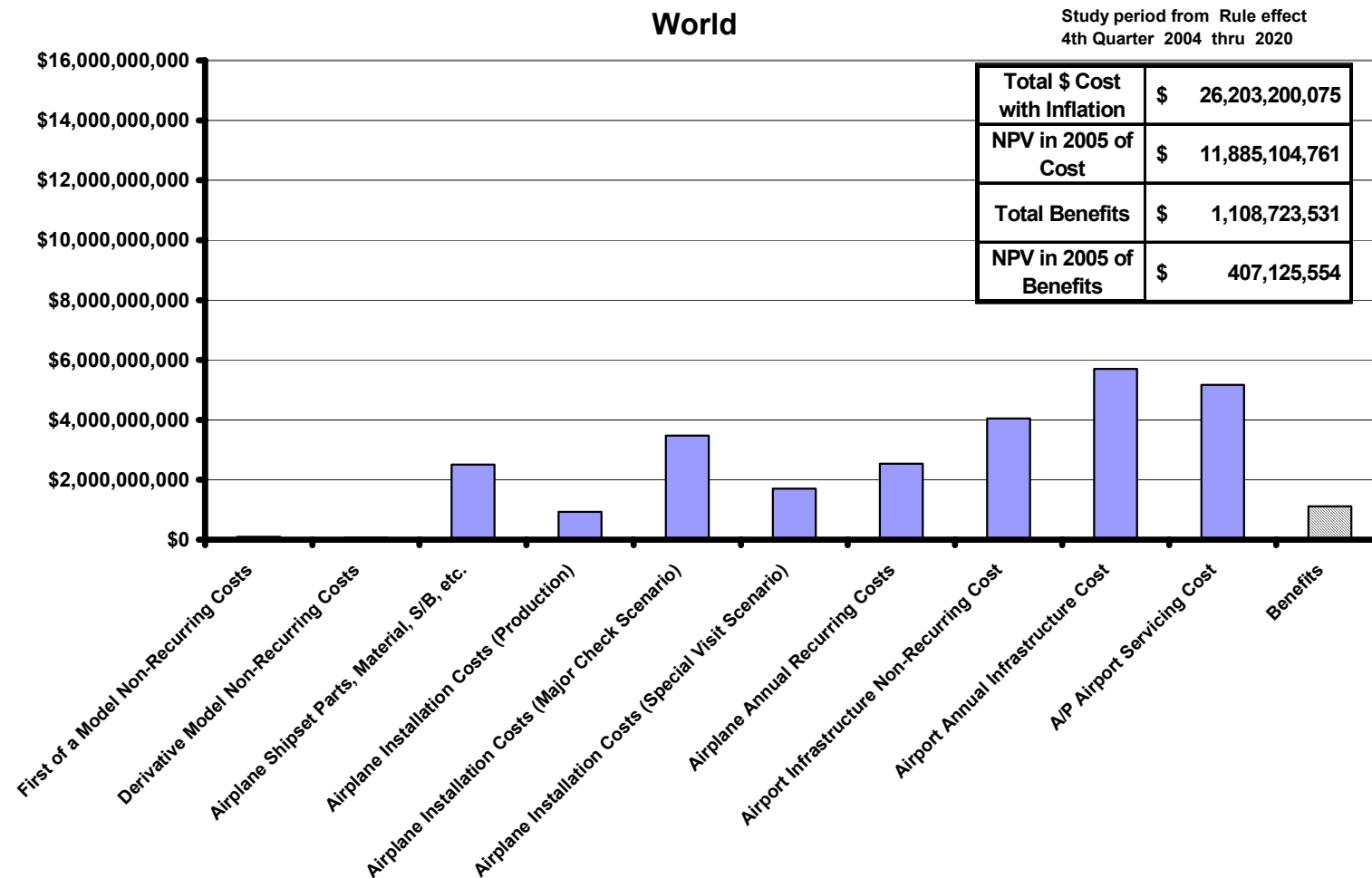


Figure G-17. Scenario 12—Ground-Based Inerting, All Fuselage Tanks, All Transports (World)

**Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

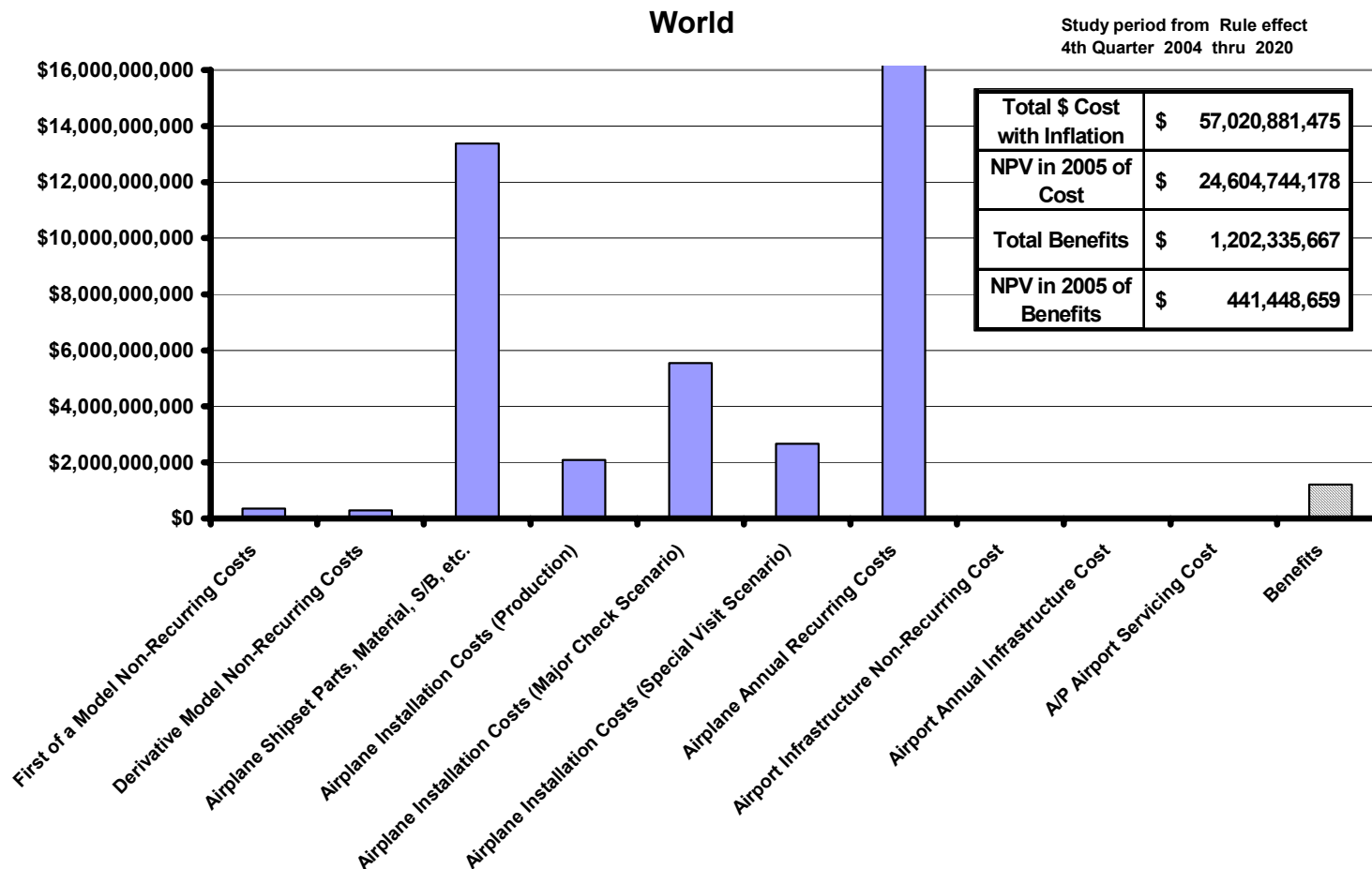


Figure G-18. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World)

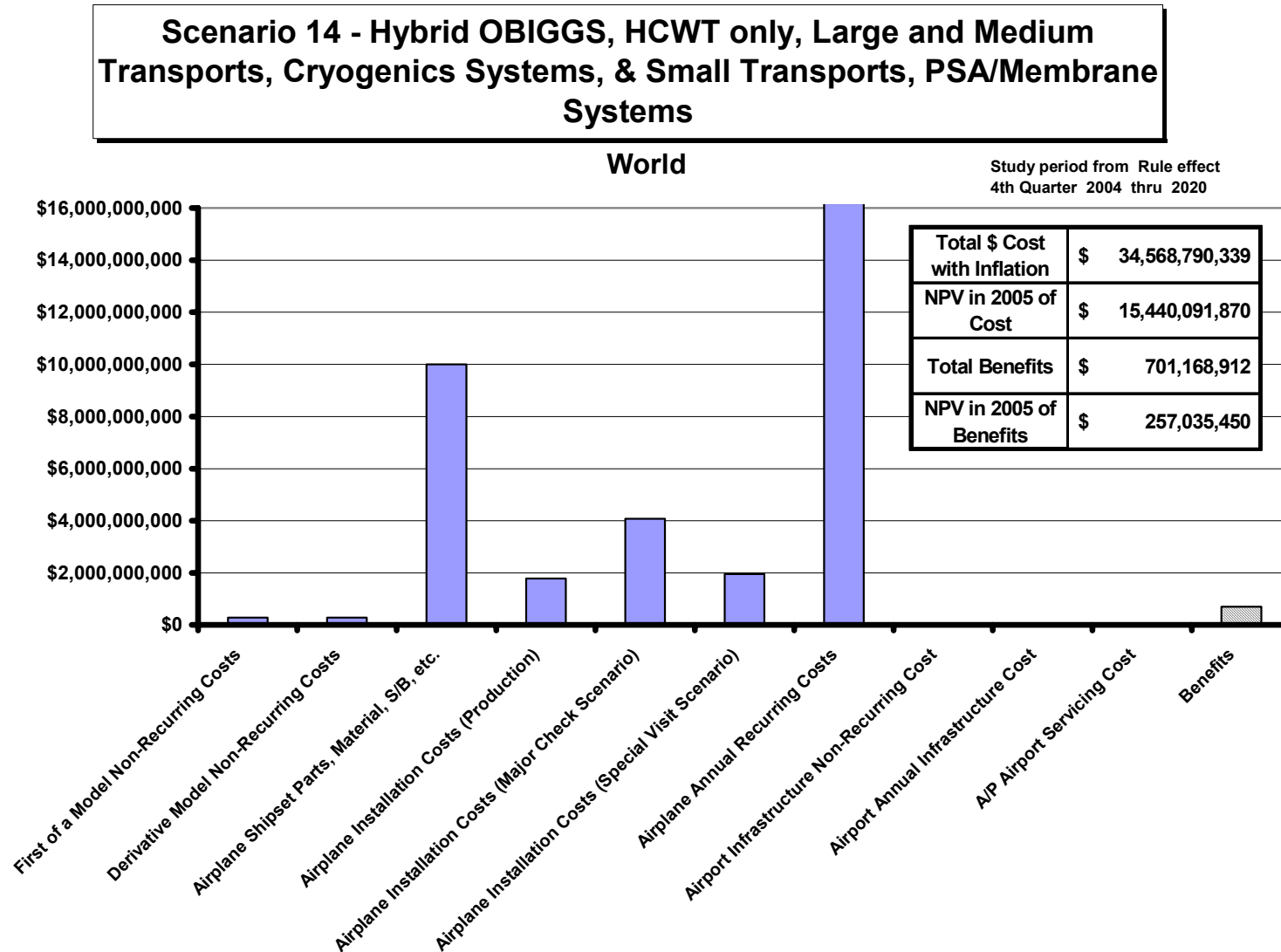


Figure G-19. Scenario 14—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World)

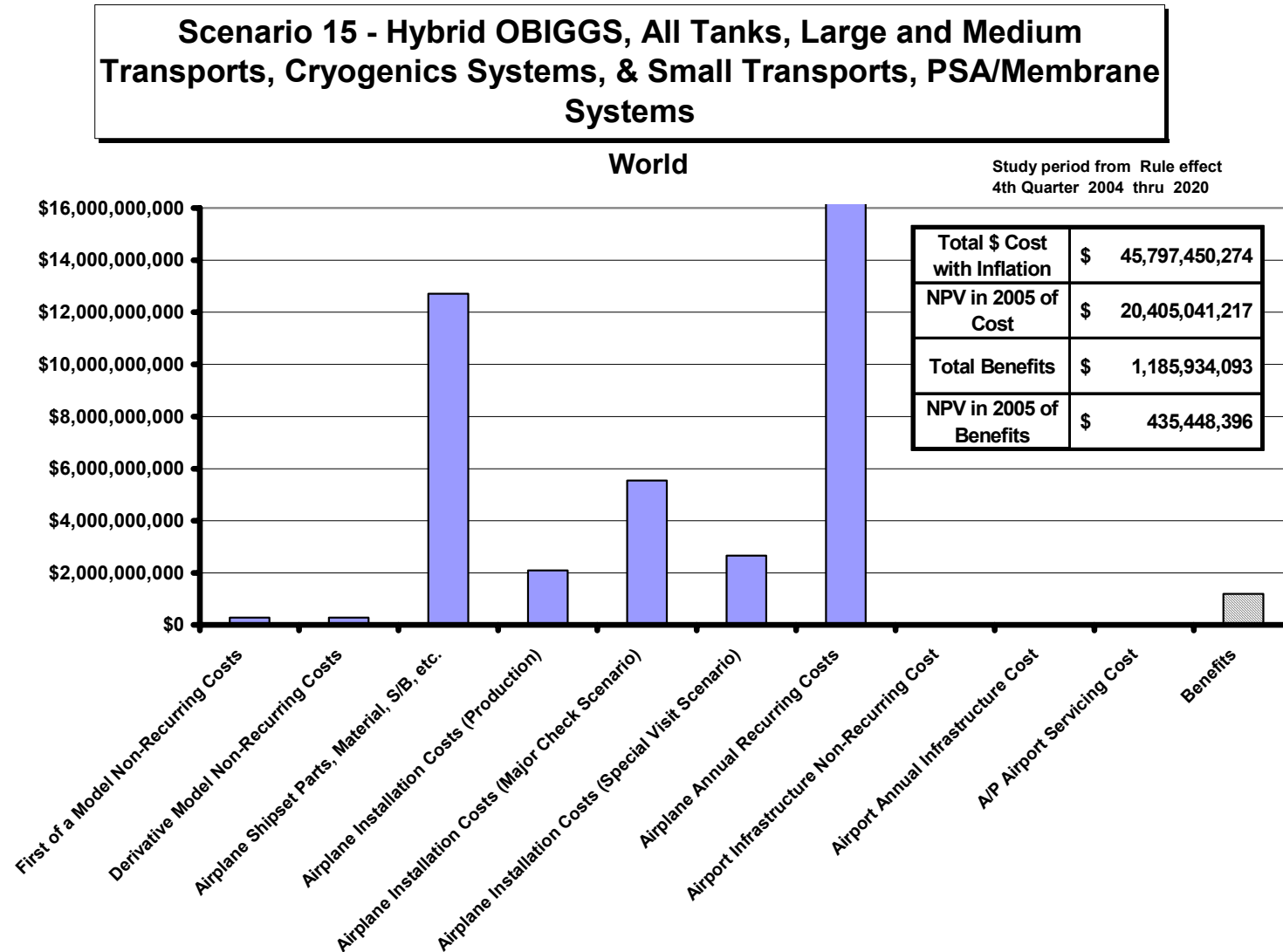


Figure G-20. Scenario 15—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World)

## Scenario 16 - On-Board Liquid Nitrogen Inerting

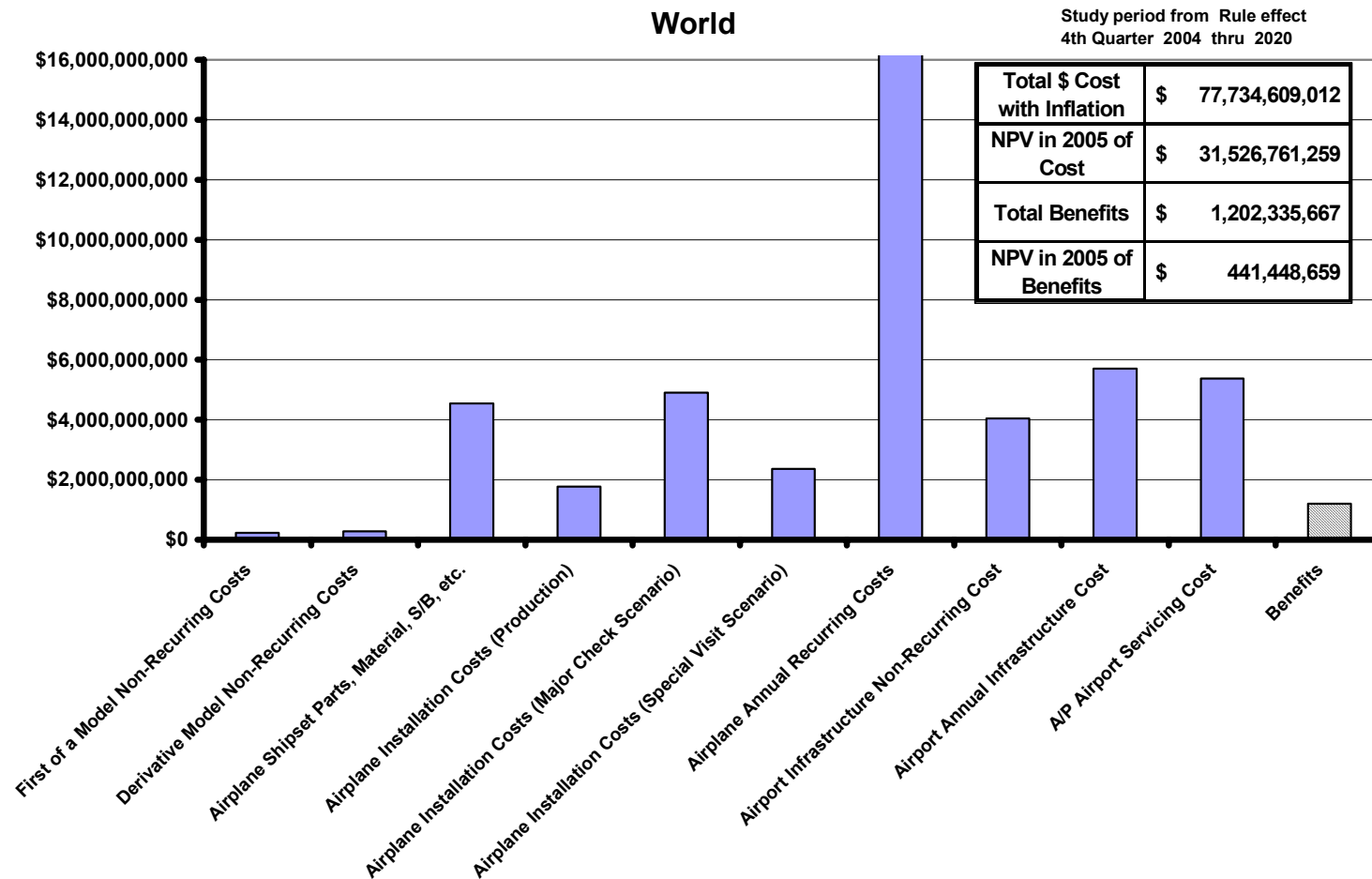


Figure G-21. Scenario 16—Onboard Liquid Nitrogen Inerting (World)

Summary of Inerting Scenario Results

World - PAX Only

Values in Millions	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems Scenario 2 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems Scenario 4 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems Scenario 11 - Ground Based Inerting HCWT only, All Tanks, All Transports Scenario 12 - Ground Based Inerting HCWT only, All Tanks, All Transports Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems Scenario 16 - On-Board Liquid Nitrogen Inerting															
Total \$ Cost with Inflation	21,474	34,897	20,722	32,007	39,168	18,015	27,575	21,285	24,085	47,094	28,866	38,157	65,236	-	-	-
NPV in 2005 of Cost	9,936	15,576	9,644	14,371	17,248	8,376	12,590	9,600	10,907	20,489	12,994	17,129	26,698	-	-	-
Total Benefits	597	1,037	591	1,032	1,202	701	1,186	668	1,109	1,202	701	1,186	1,202	-	-	-
NPV in 2005 of Benefits	219	381	217	379	441	257	435	245	407	441	257	435	441	-	-	-

Figure G-22. Cost Summary of World Fleet Passenger Only

**Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

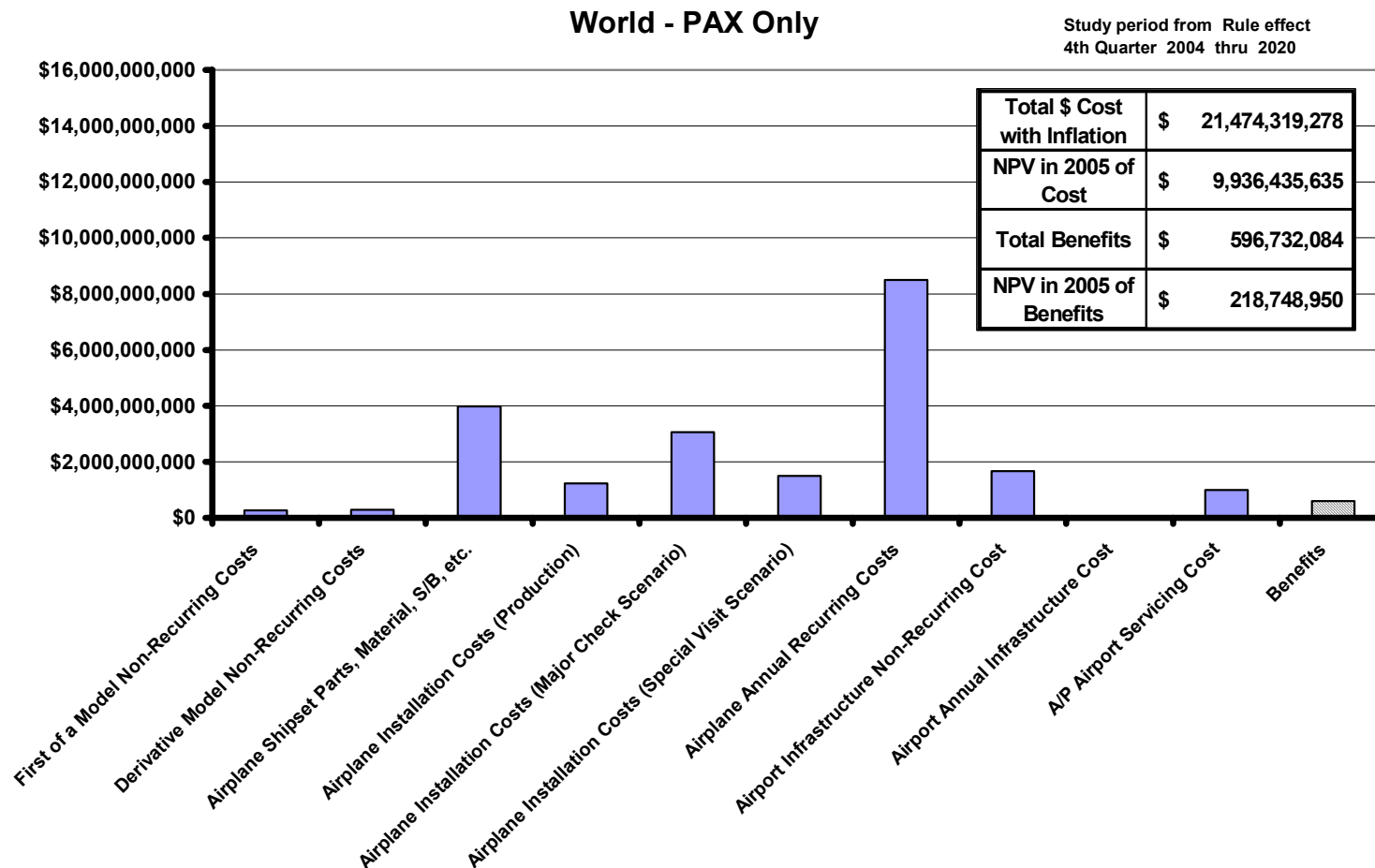


Figure G-23. Scenario 1—Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (World, Passenger Only)

**Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

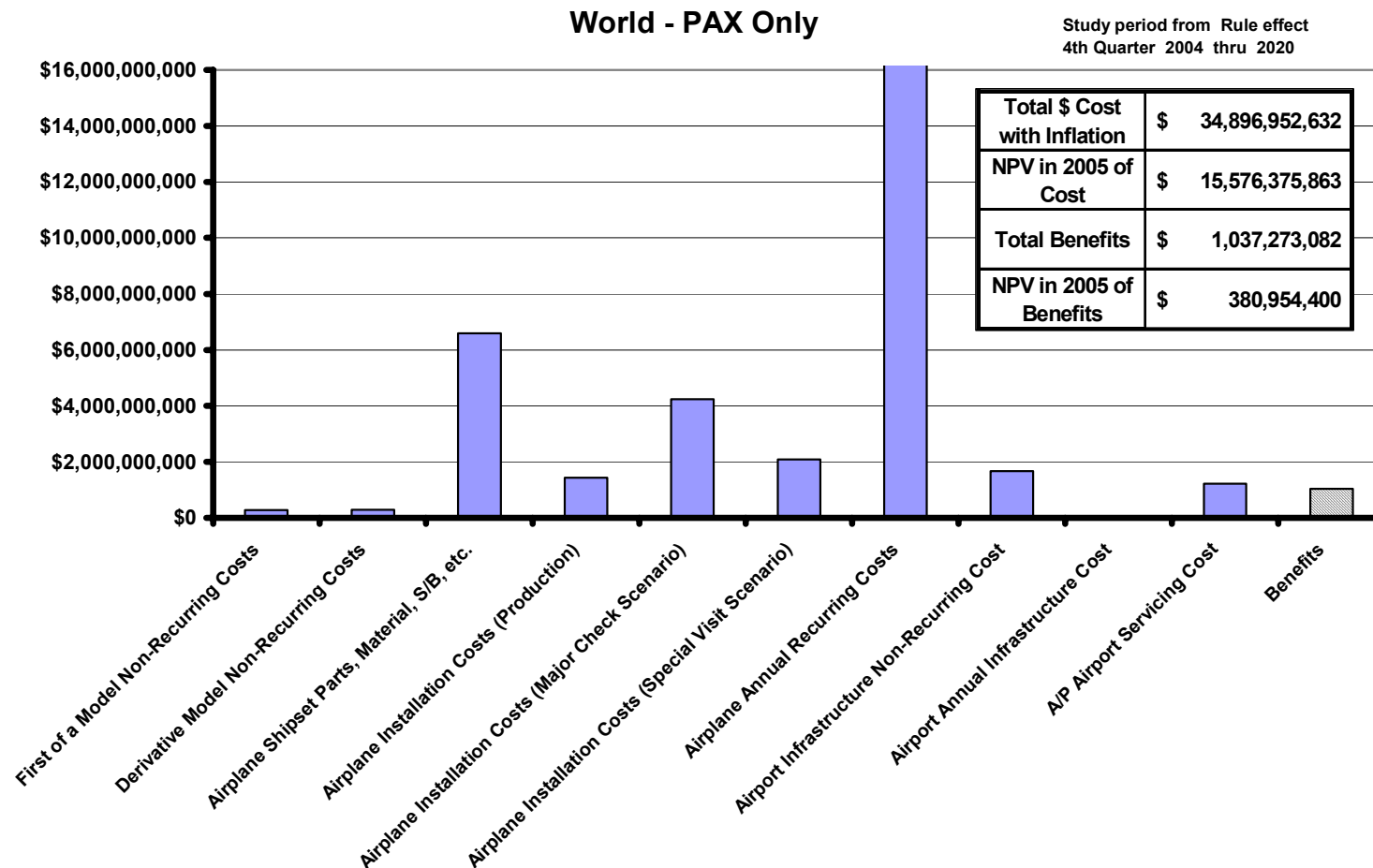


Figure G-24. Scenario 2—Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (World, Passenger Only)

**Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

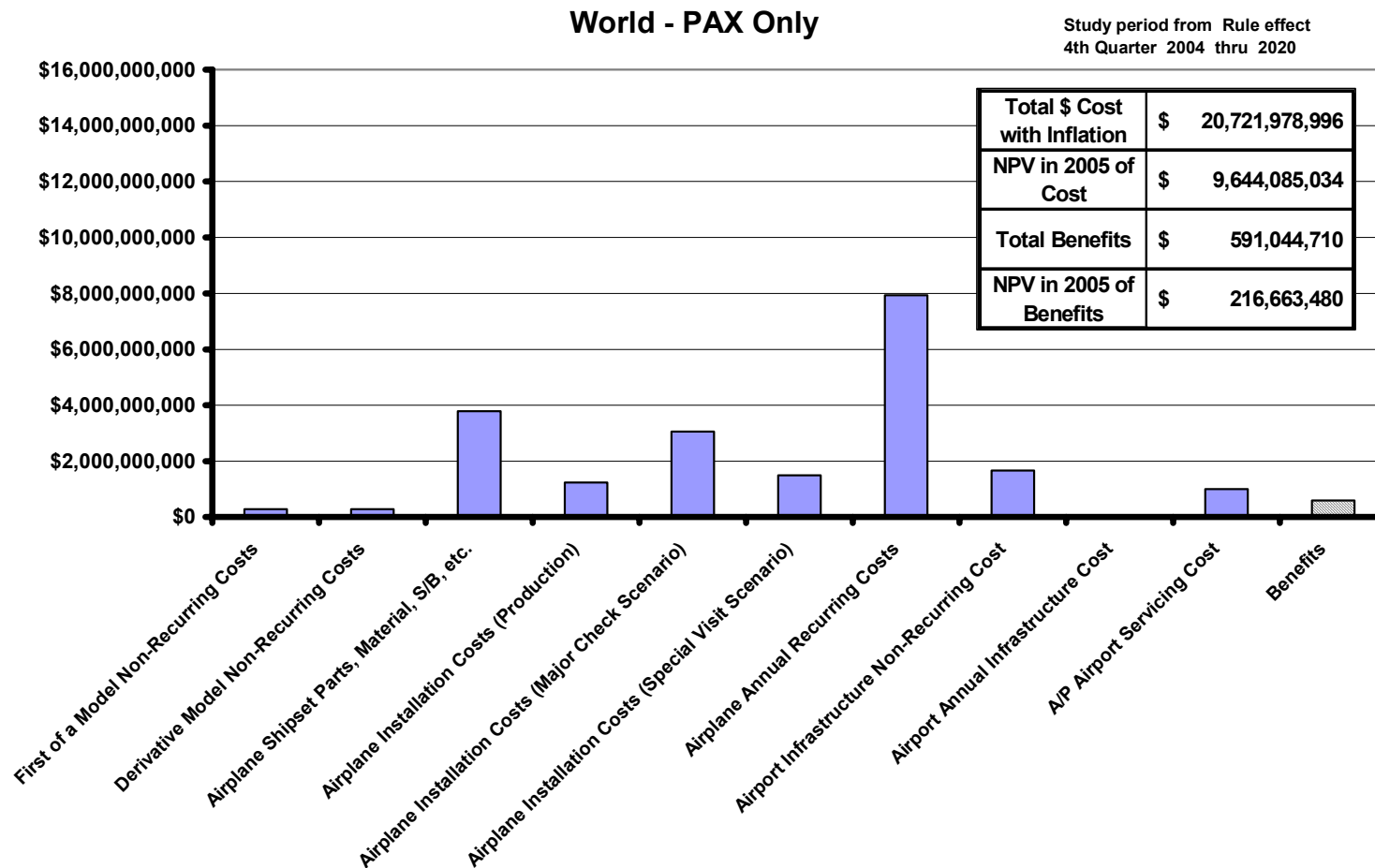


Figure G-25. Scenario 3—Hybrid Onboard Ground Inerting, HCWT Only, Large, Medium and Small Transports, PSA/Membrane Systems (World, Passenger Only)

**Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

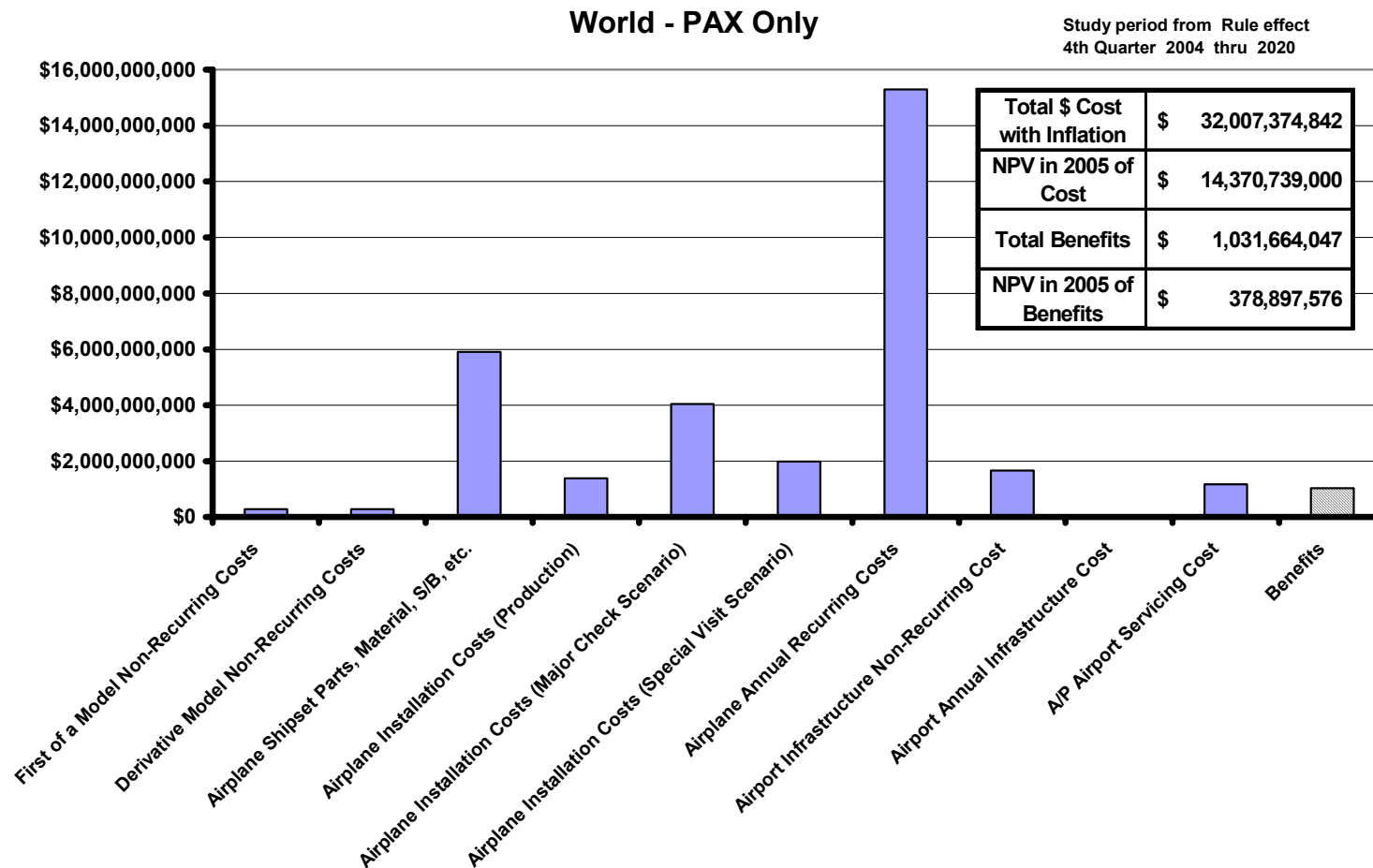


Figure G-26. Scenario 4—Hybrid Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (World, Passenger Only)

**Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

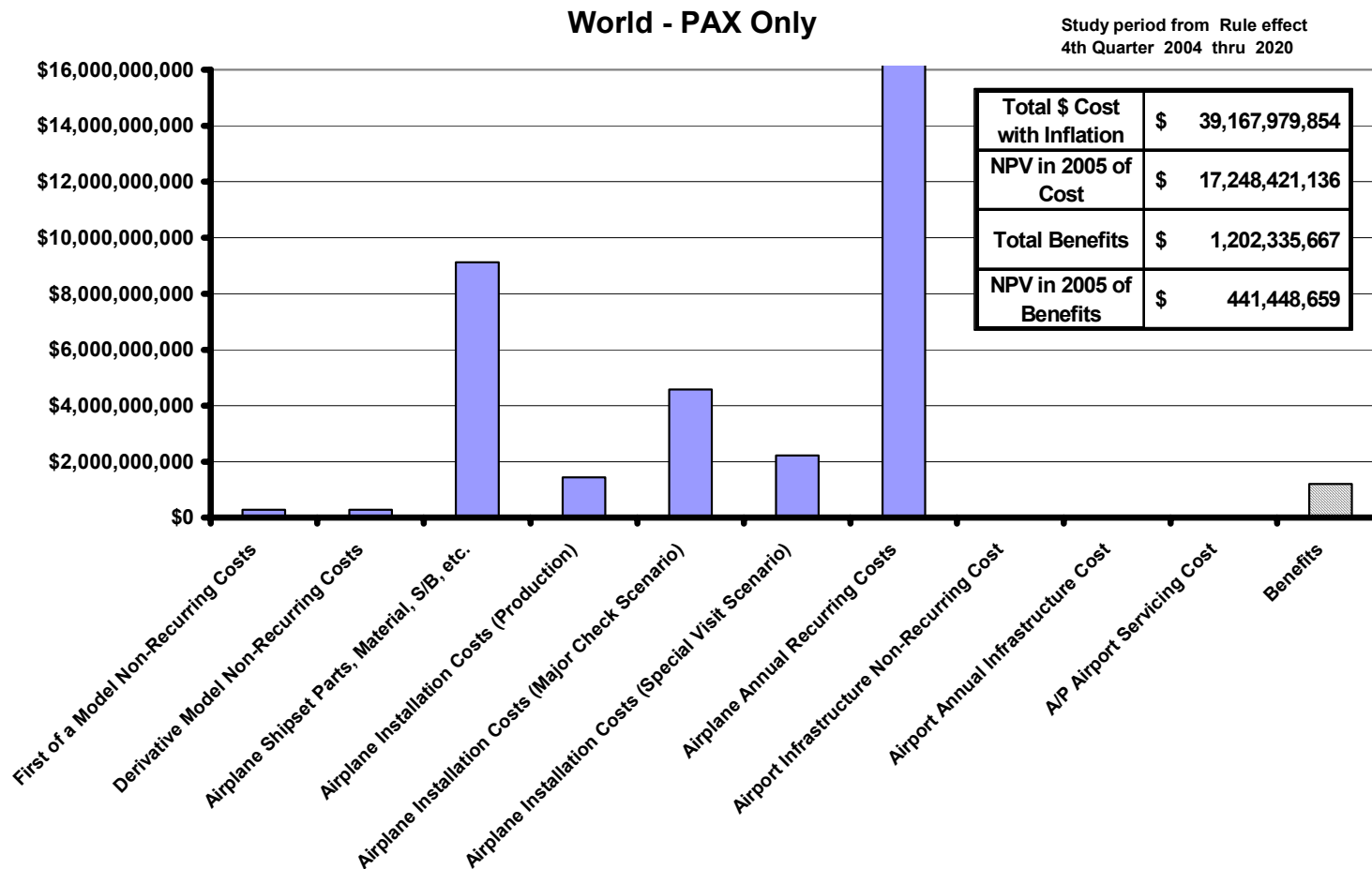


Figure G-27. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

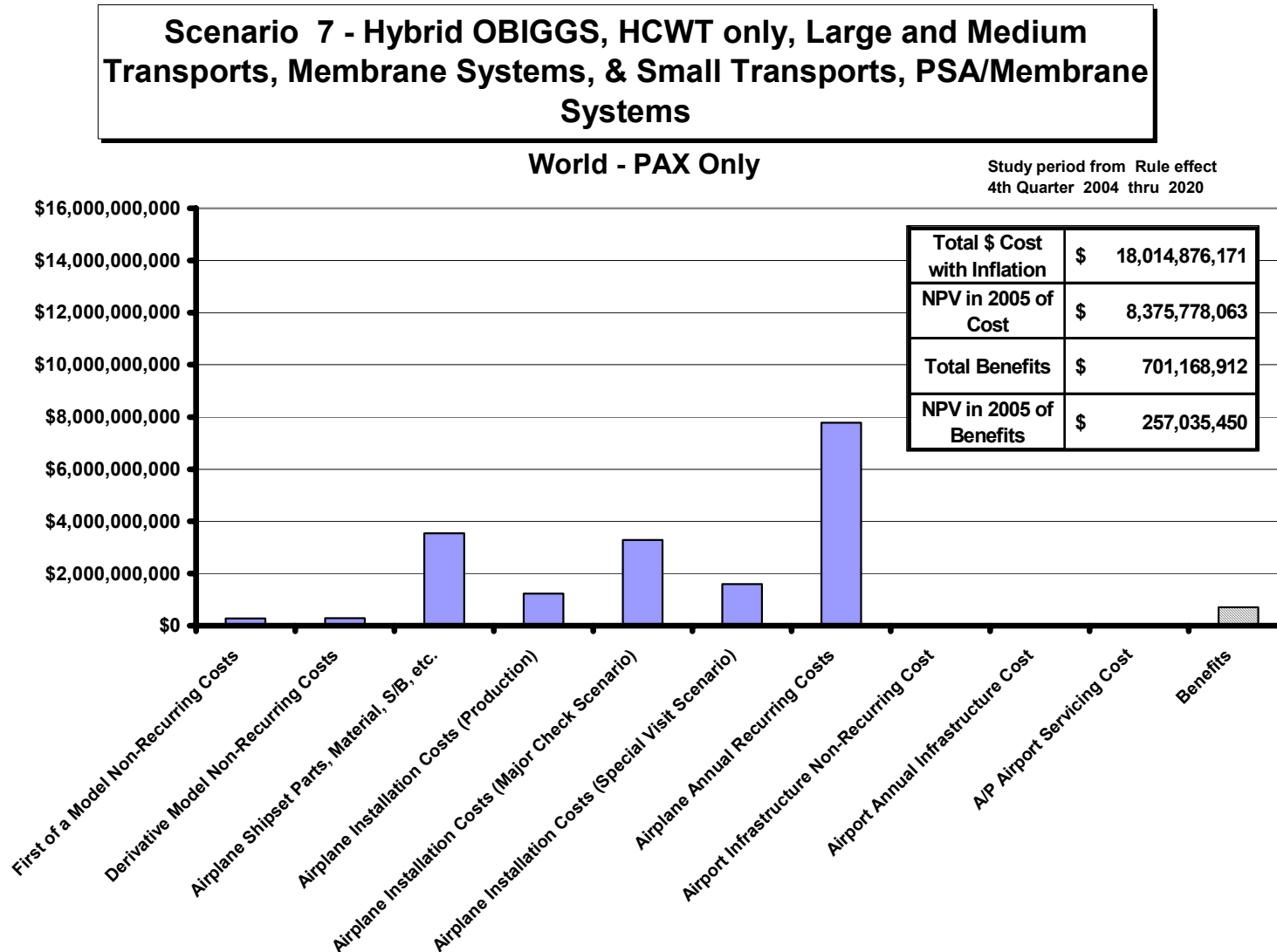


Figure G-28. Scenario 7—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

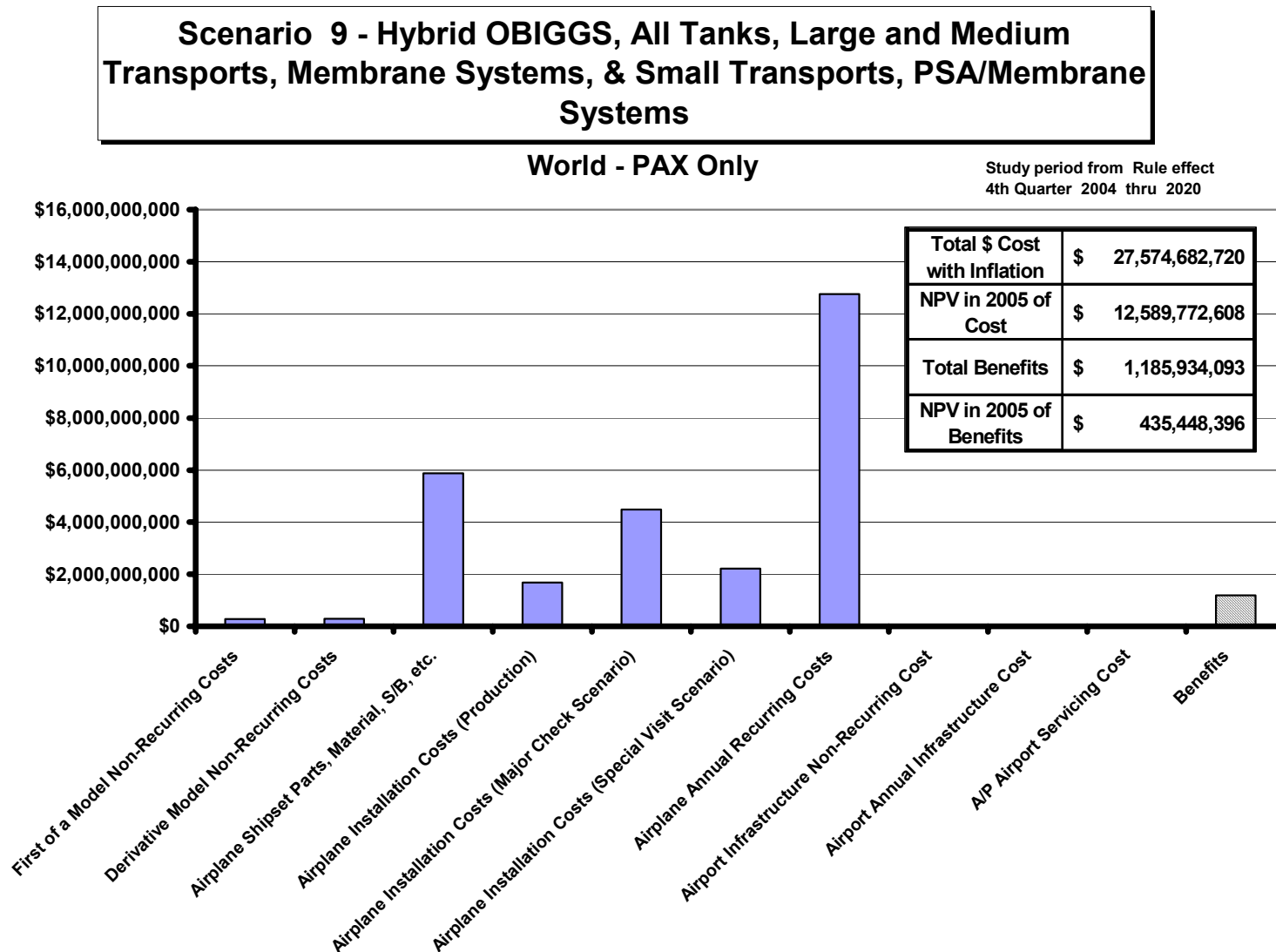


Figure G-29. Scenario 9—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

**Scenario 11 - Ground Based Inerting HCWT only, All Transports**

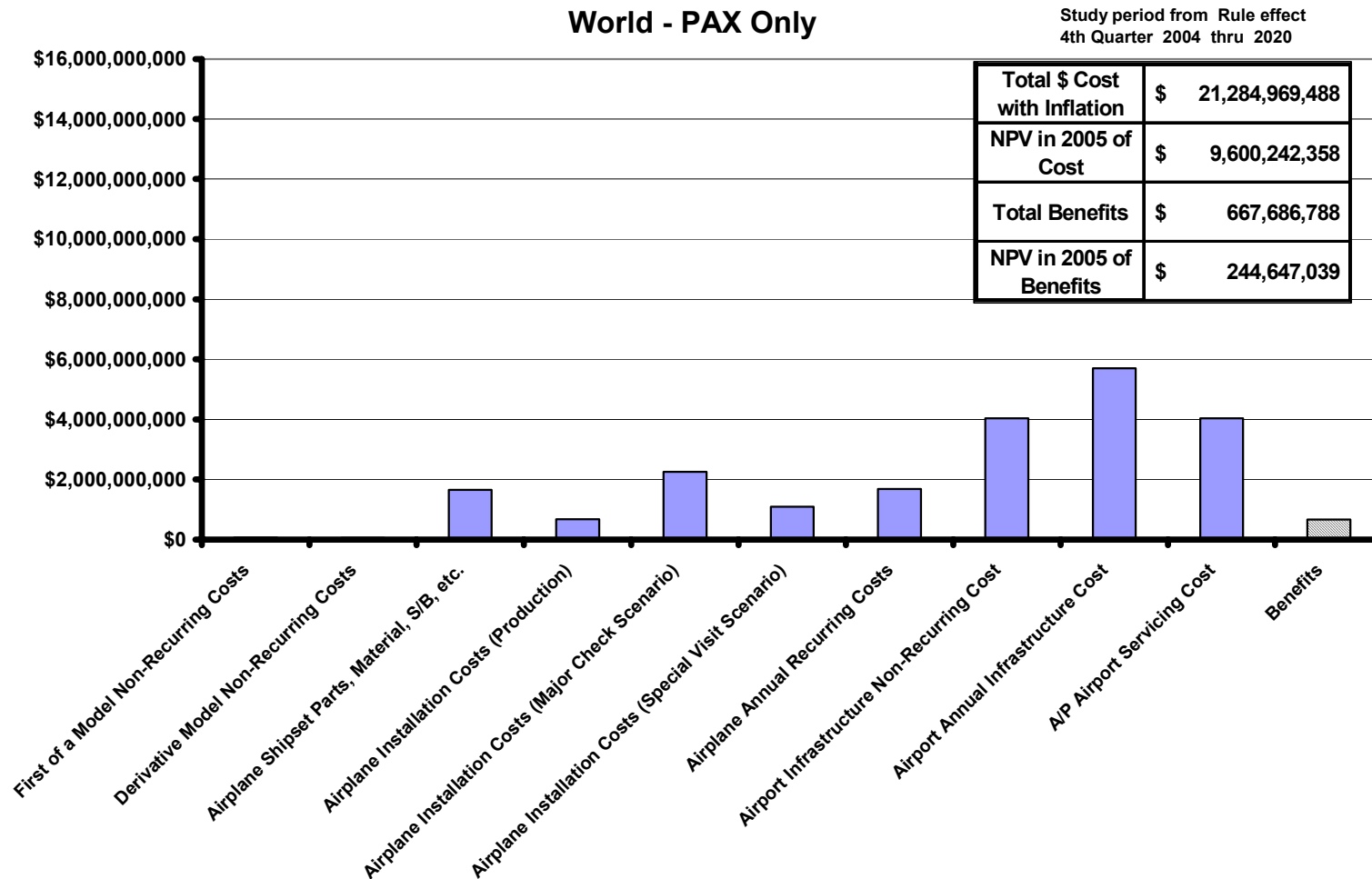


Figure G-30. Scenario 11—Ground-Based Inerting, HCWT Only, All Transports (World, Passenger Only)

## Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports

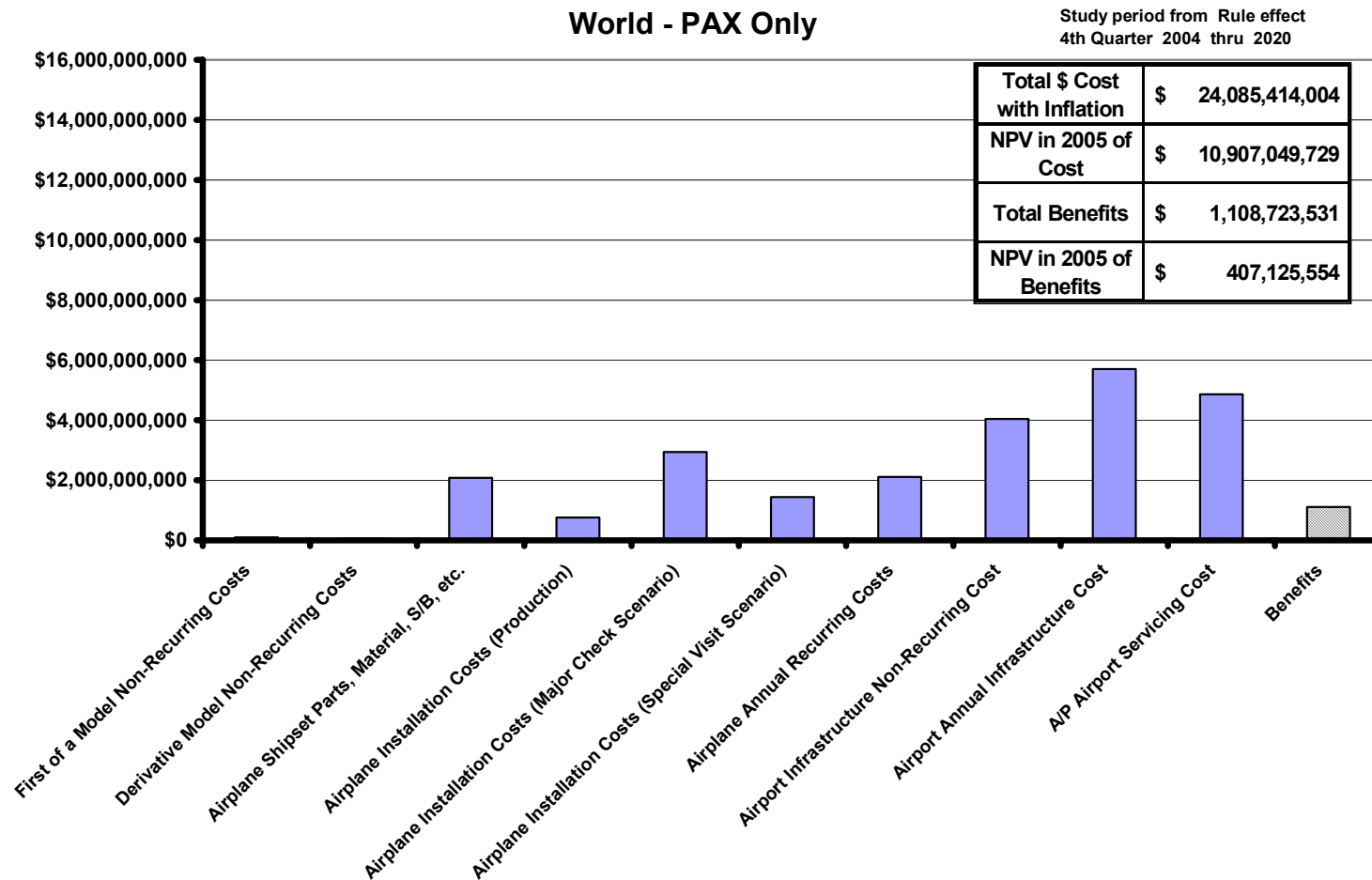


Figure G-31. Scenario 12—Ground-Based Inerting, All Fuselage Tanks, All Transports (World, Passenger Only)

**Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

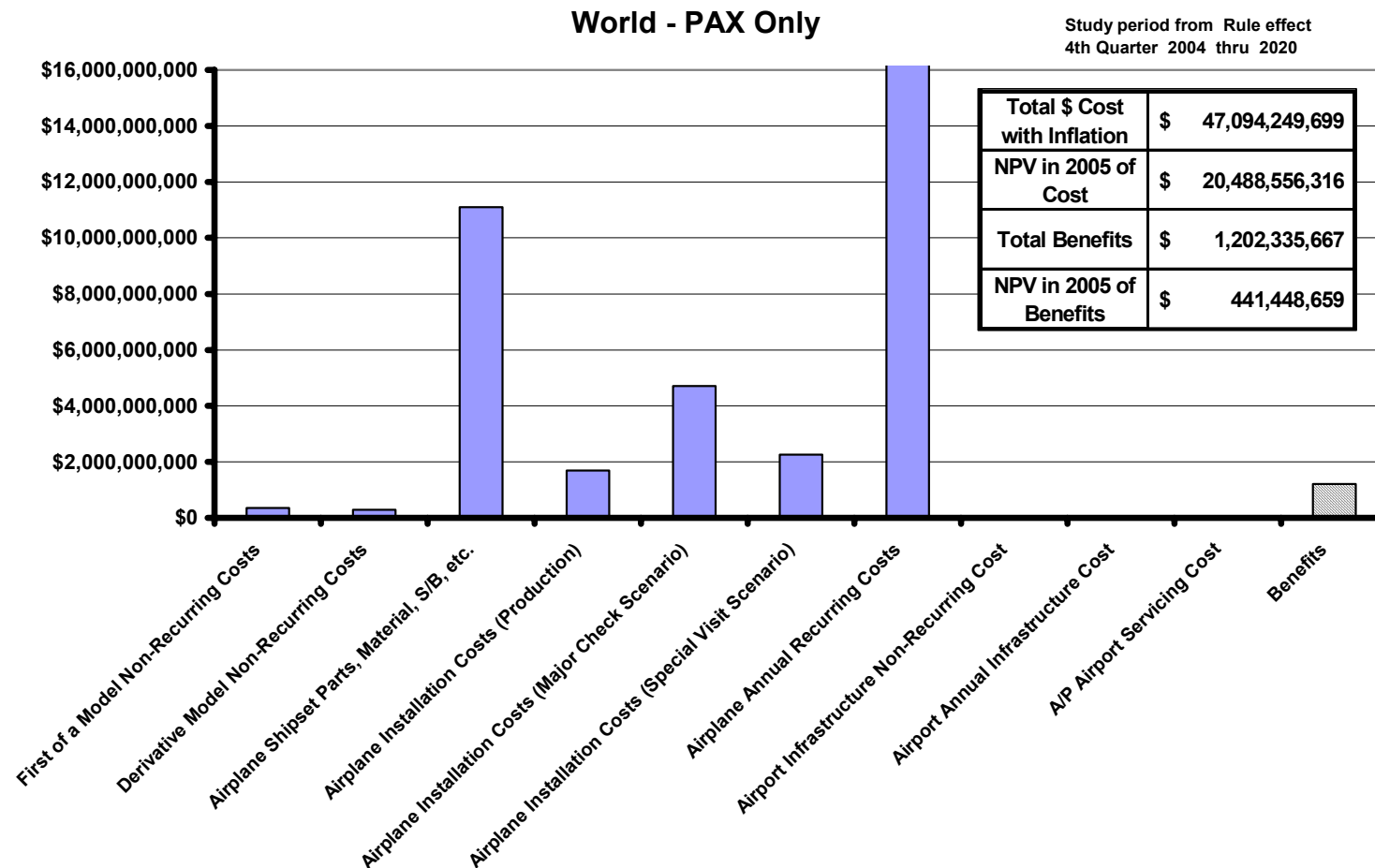


Figure G-32. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

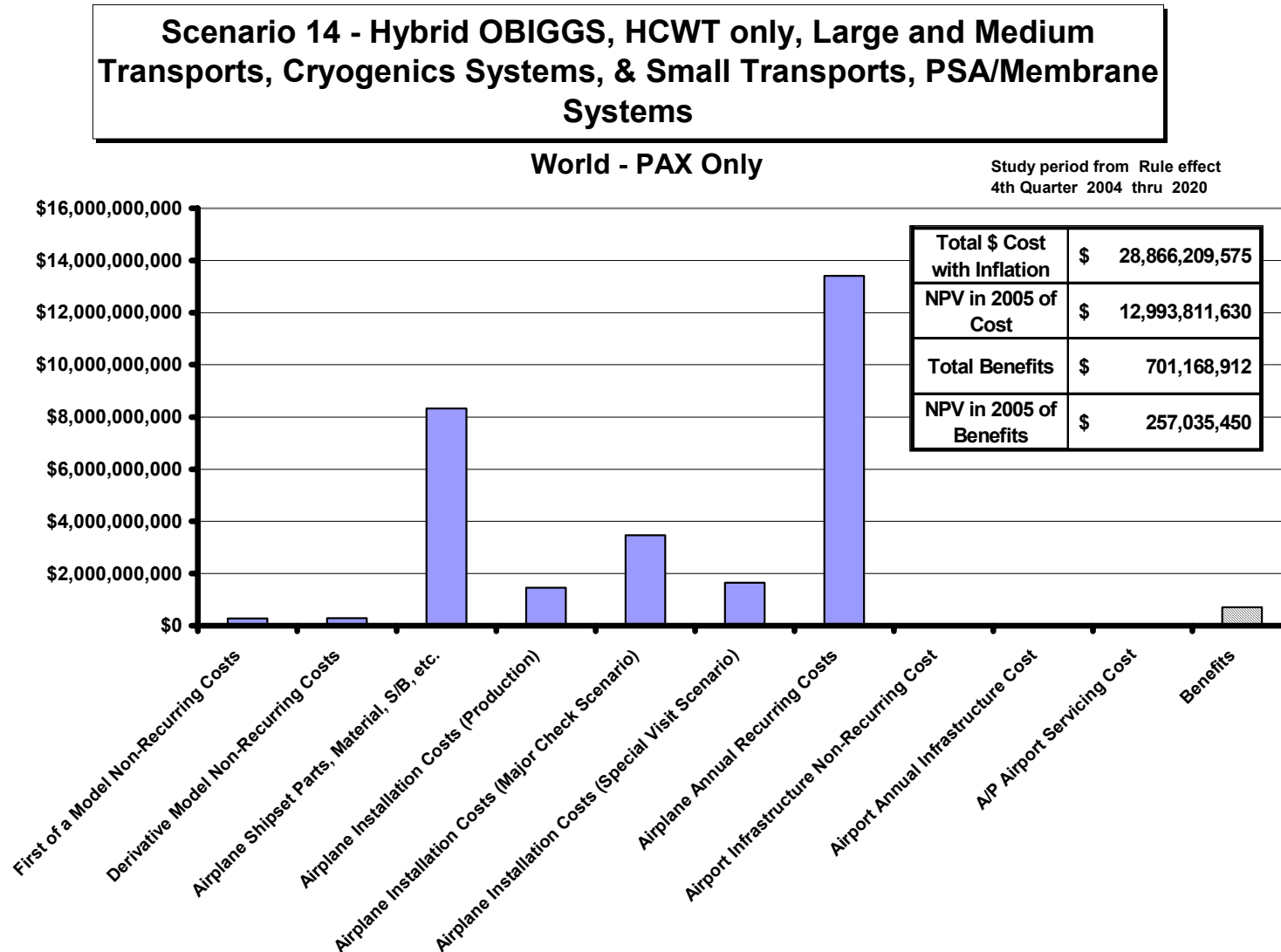


Figure G-33. Scenario 14—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

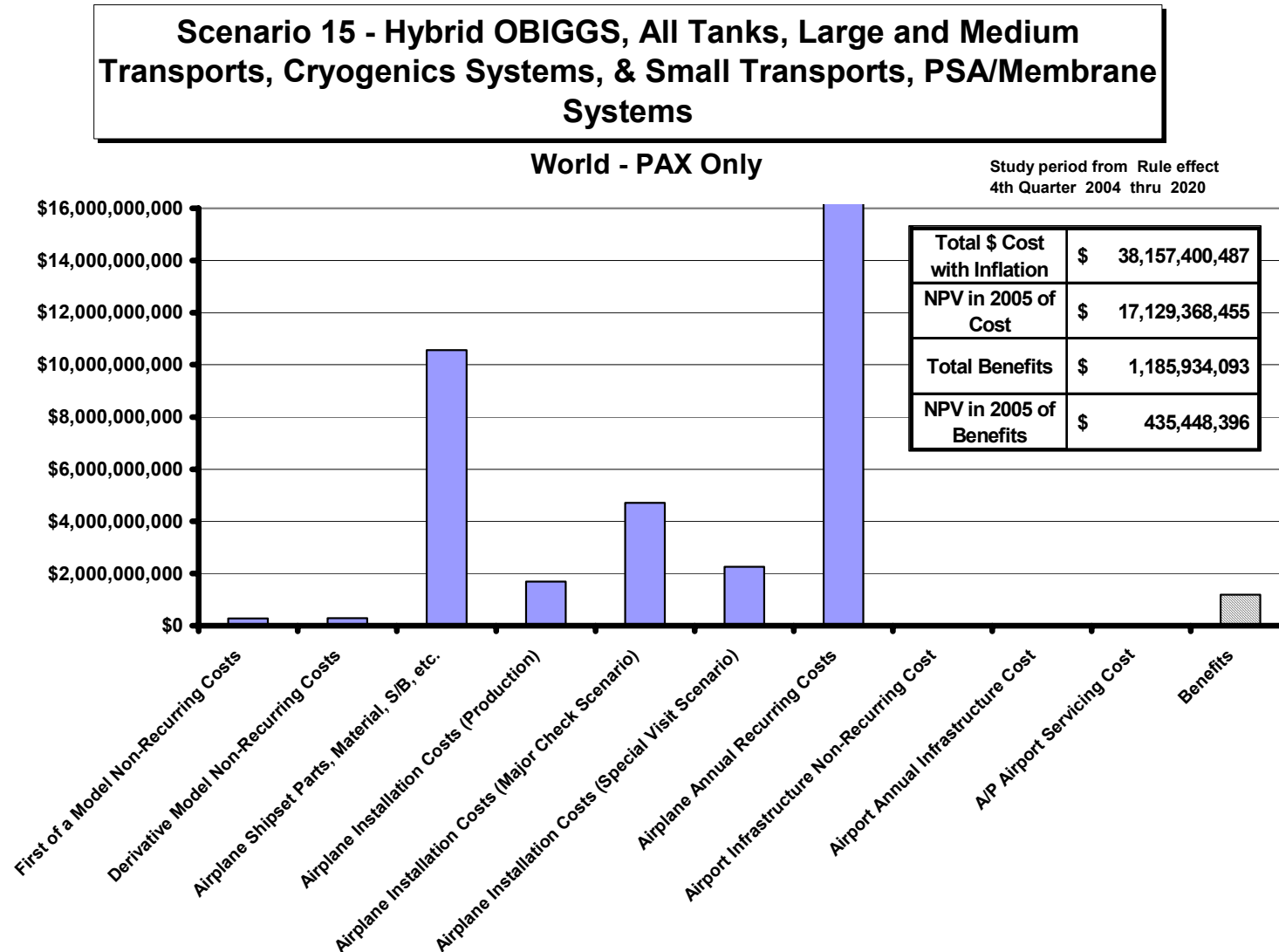


Figure G-34. Scenario 15—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (World, Passenger Only)

## Scenario 16 - On-Board Liquid Nitrogen Inerting

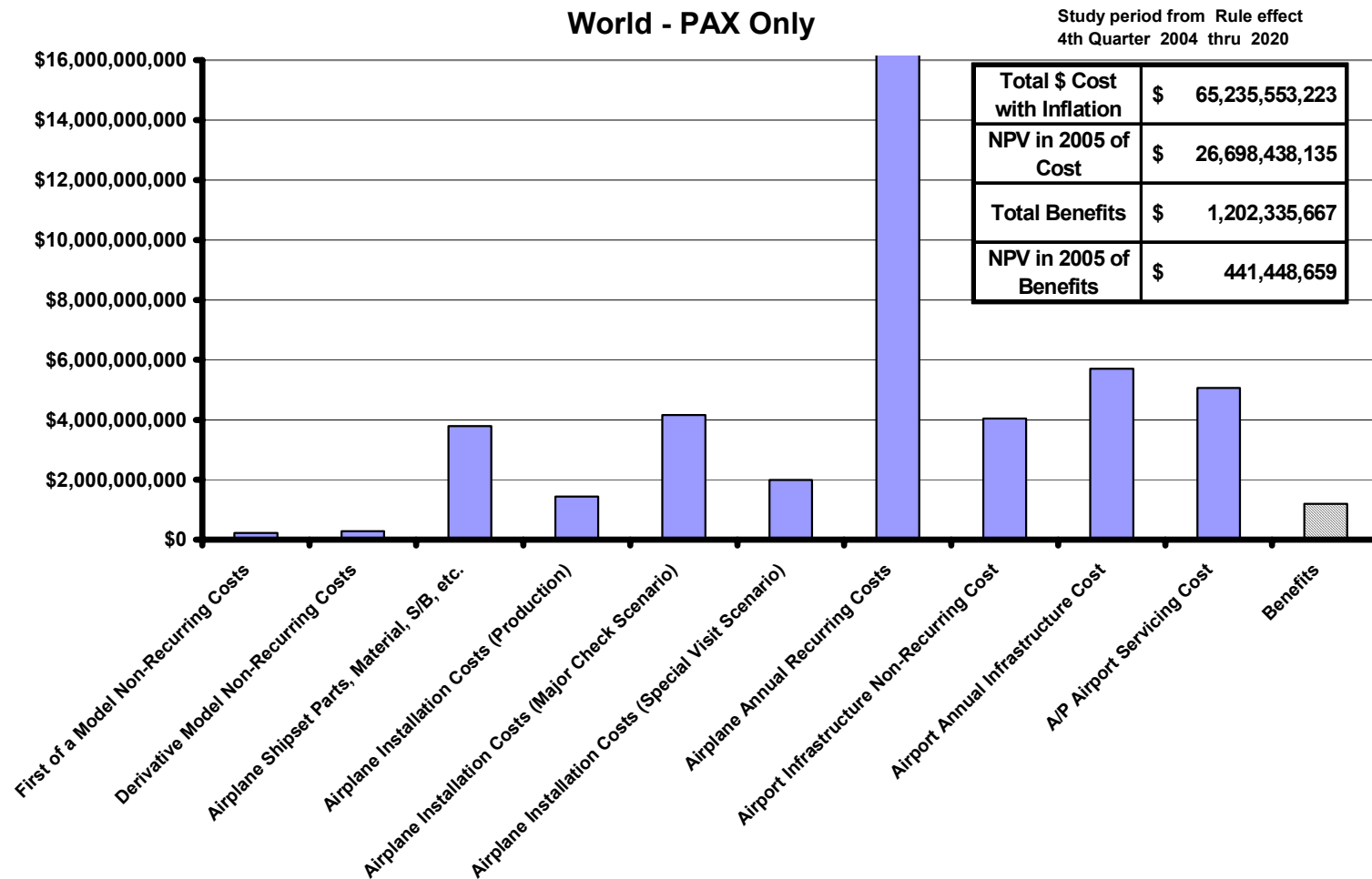


Figure G-35. Scenario 16—Onboard Liquid Nitrogen Inerting (World, Passenger Only)

# Estimating and Forecasting Task Team Final Report

## Summary of Inerting Scenario Results

## US-Operator

Values in Millions

	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 2 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 6 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 8 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 10 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 11 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 12 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting
Total \$ Cost with Inflation	10,082	15,367	9,744	14,203	17,047	8,606	12,680	10,429	11,588	20,924	13,586	17,414	27,692	-	-	-
NPV in 2005 of Cost	4,849	7,099	4,721	6,613	7,753	4,165	5,968	4,758	5,314	9,357	6,299	8,015	11,656	-	-	-
Total Benefits	233	434	231	432	497	274	492	258	459	497	274	492	497	-	-	-
NPV in 2005 of Benefits	86	159	85	159	183	101	181	95	169	183	101	181	183	-	-	-

Figure G-36. Cost Summary of U.S. Fleet

**Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

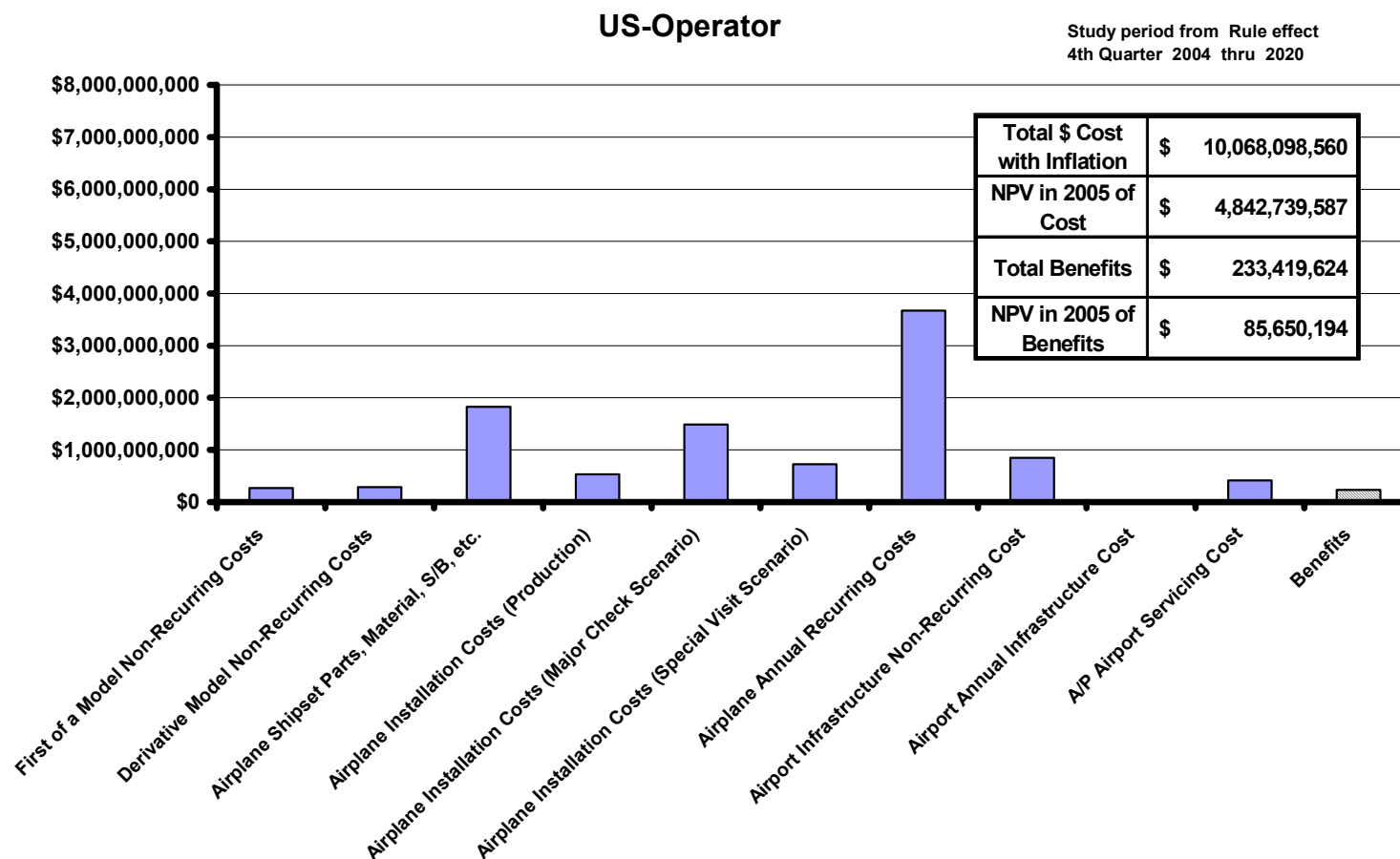


Figure G-37. Scenario 1—Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

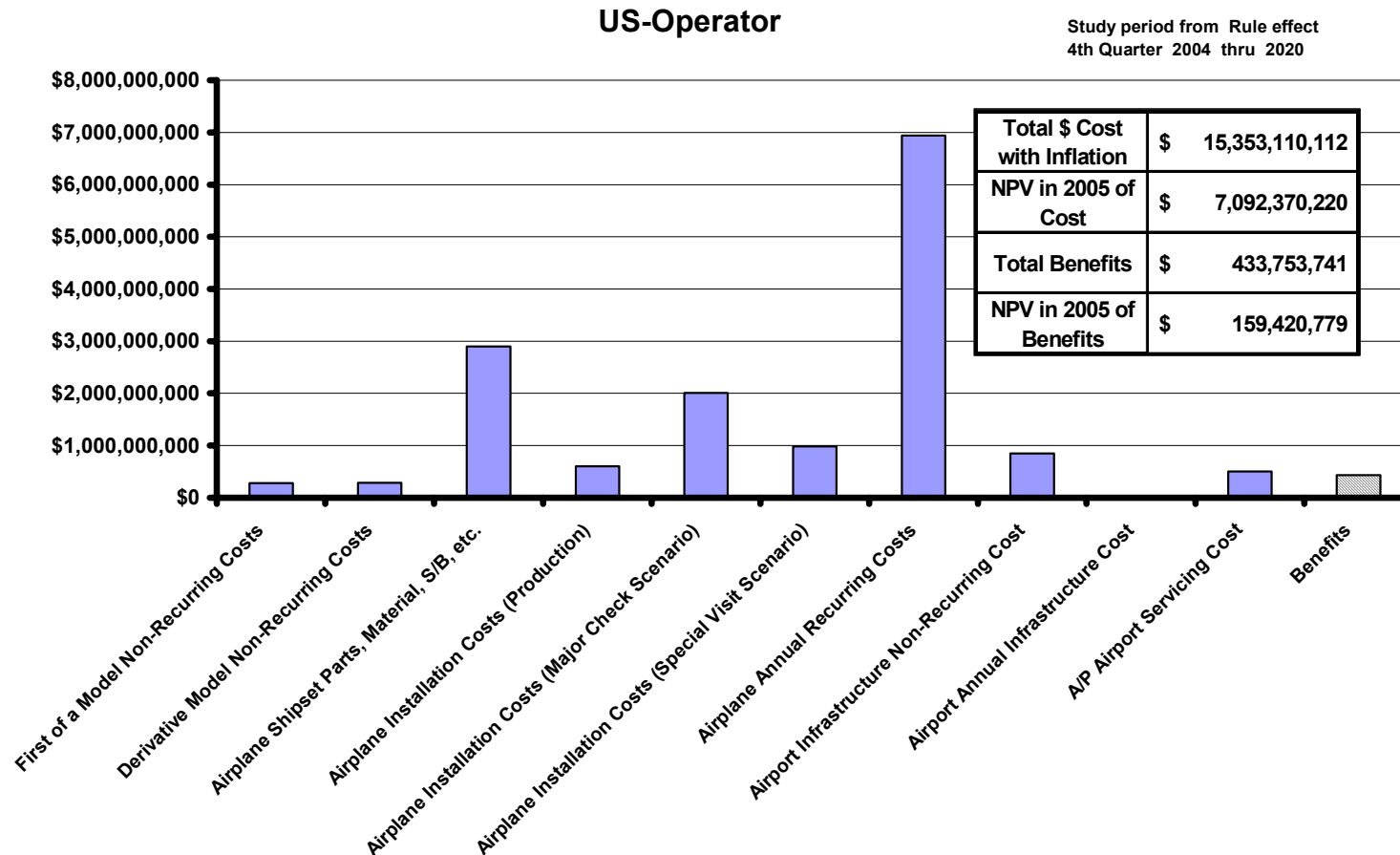


Figure G-38. Scenario 2—Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

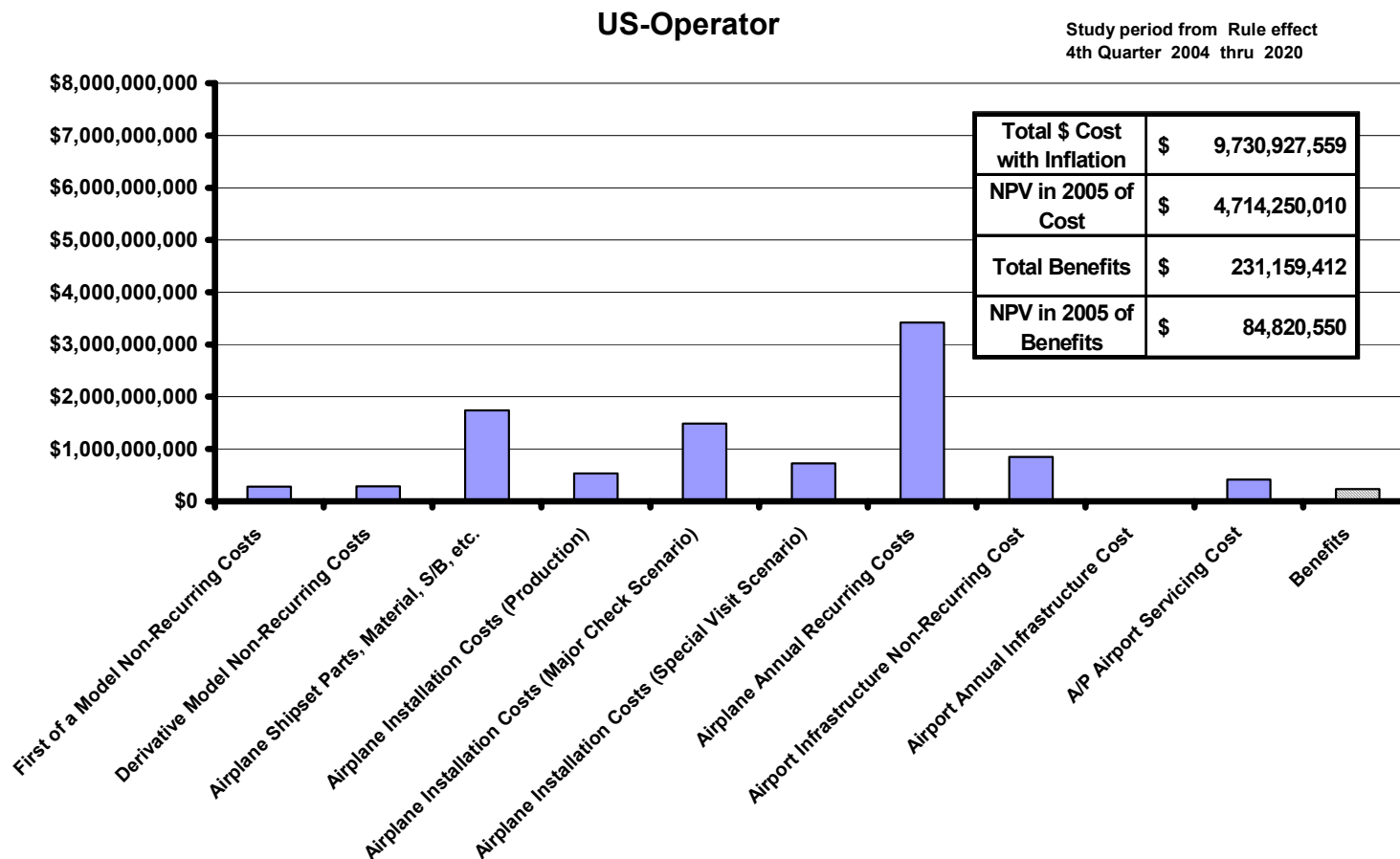


Figure G-39. Scenario 3—Hybrid Onboard Ground Inerting, HCWT Only, Large, Medium, and Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

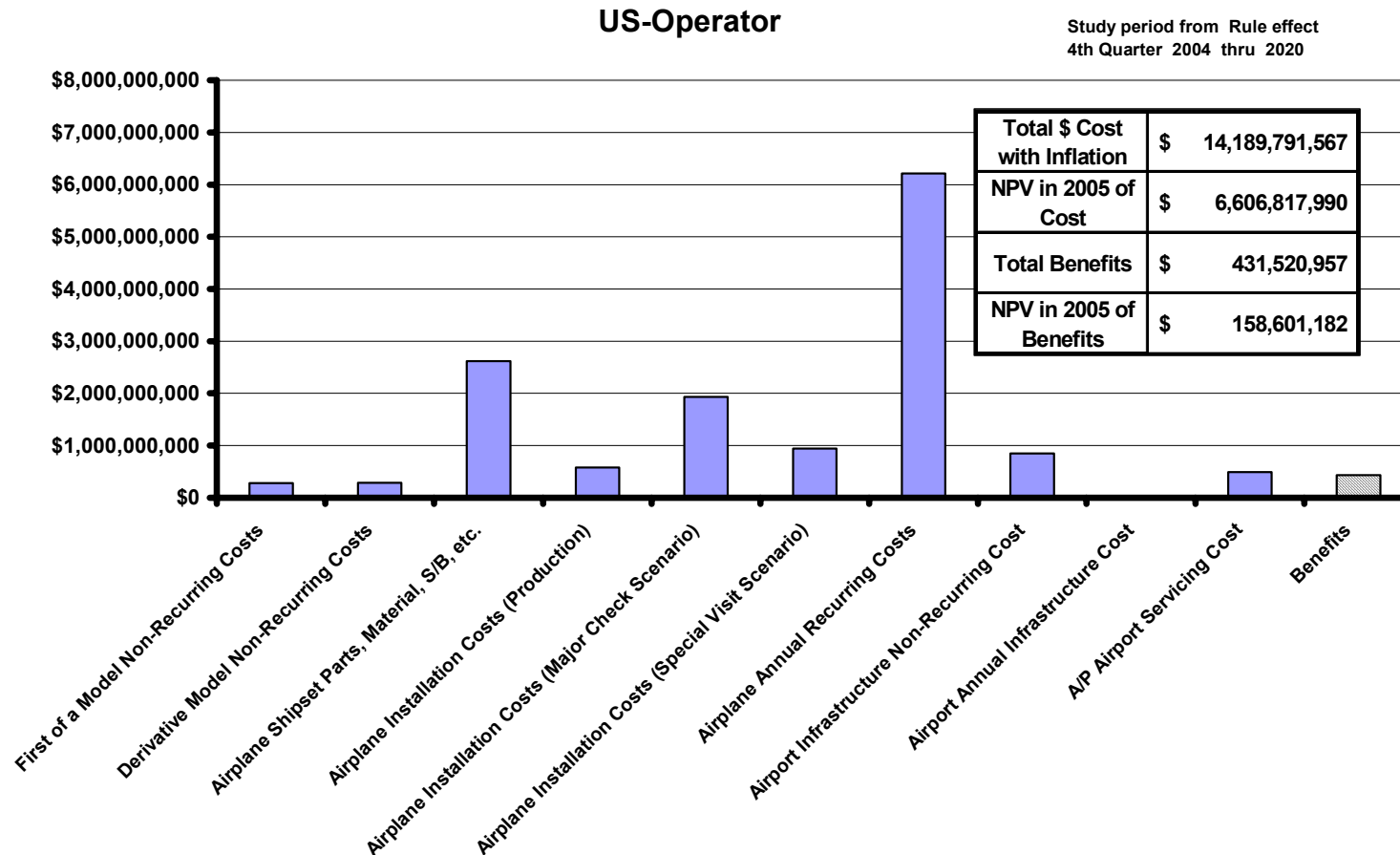


Figure G-40. Scenario 4—Hybrid Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, and Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

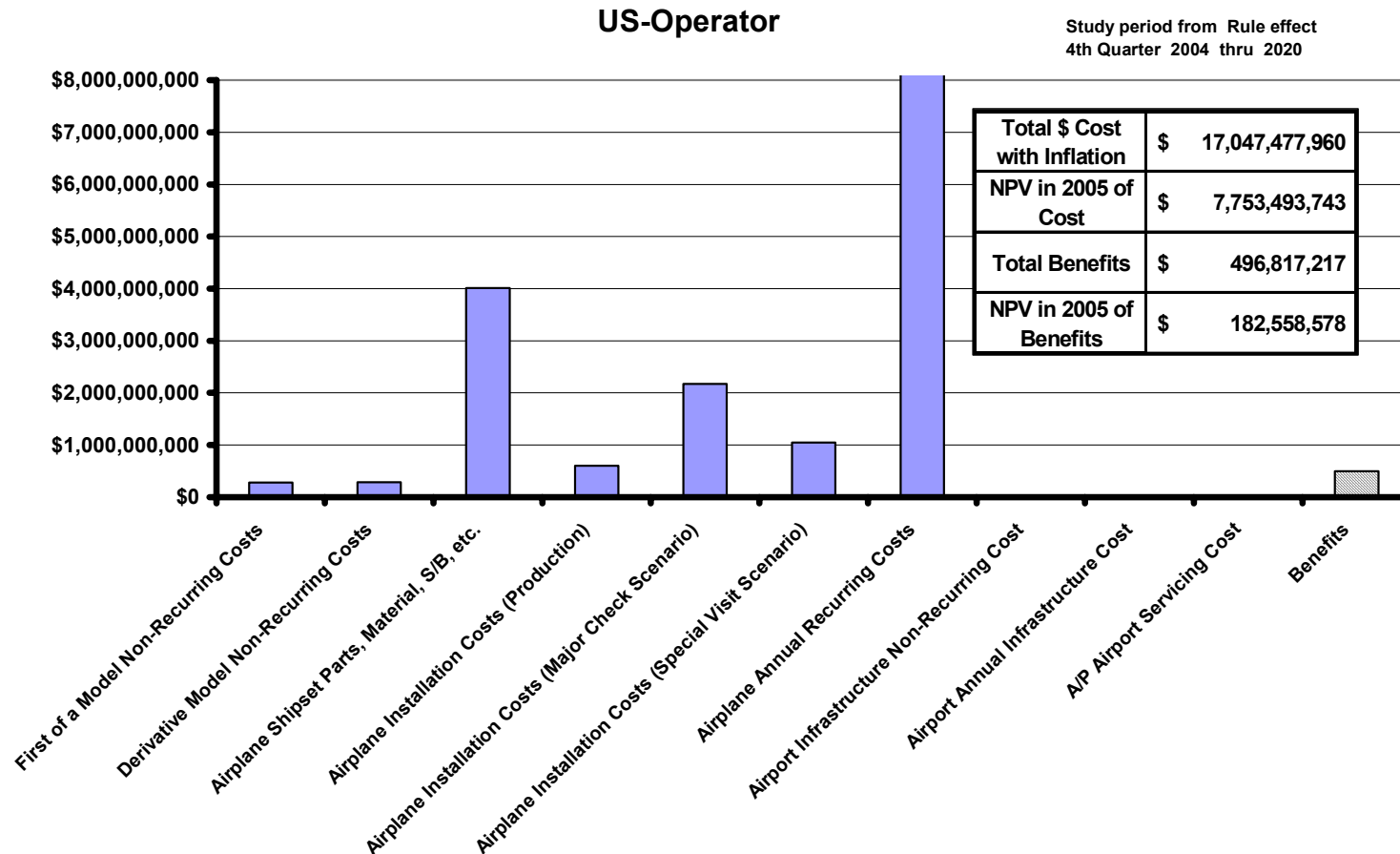


Figure G-41. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

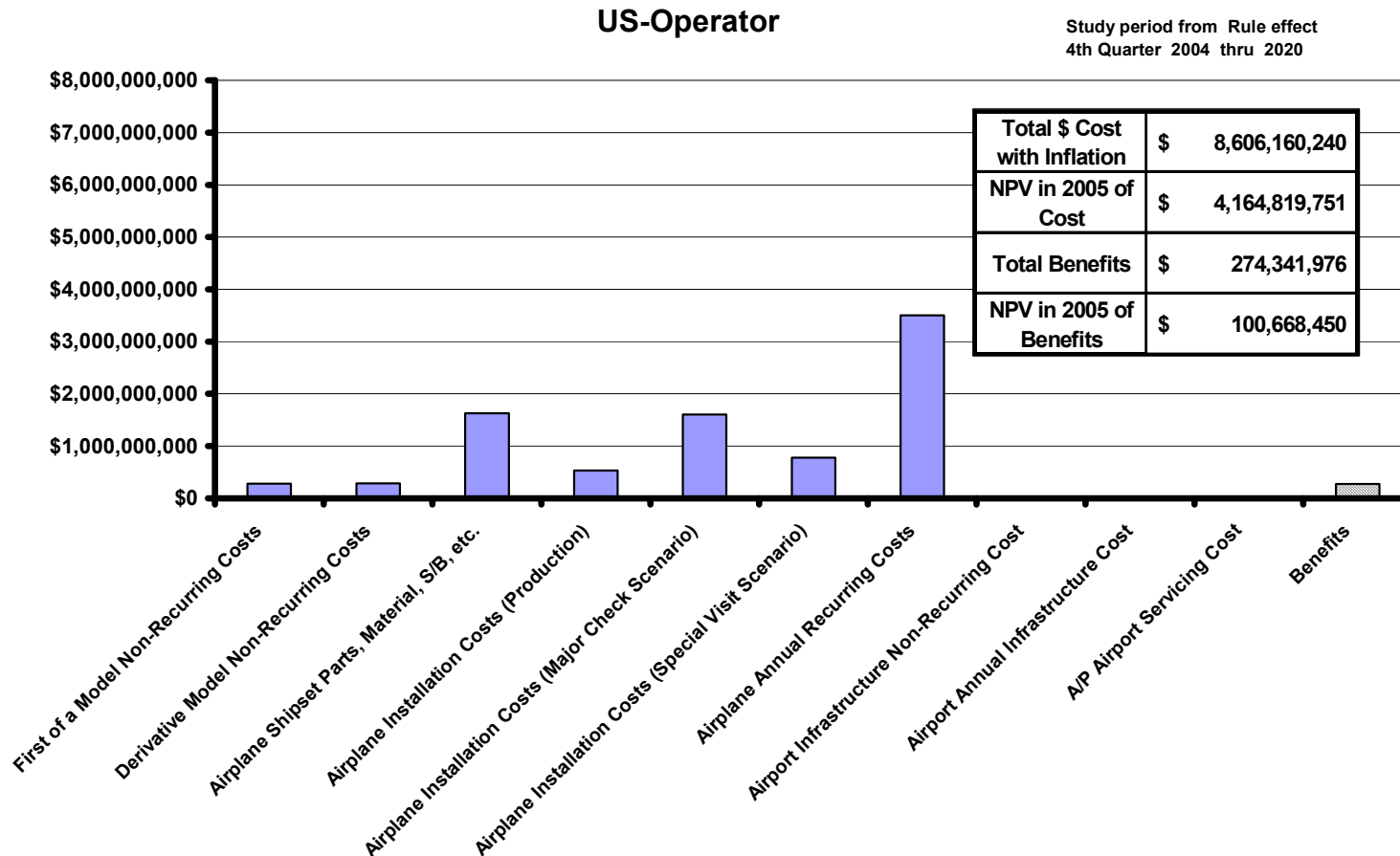


Figure G-42. Scenario 7—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S.)

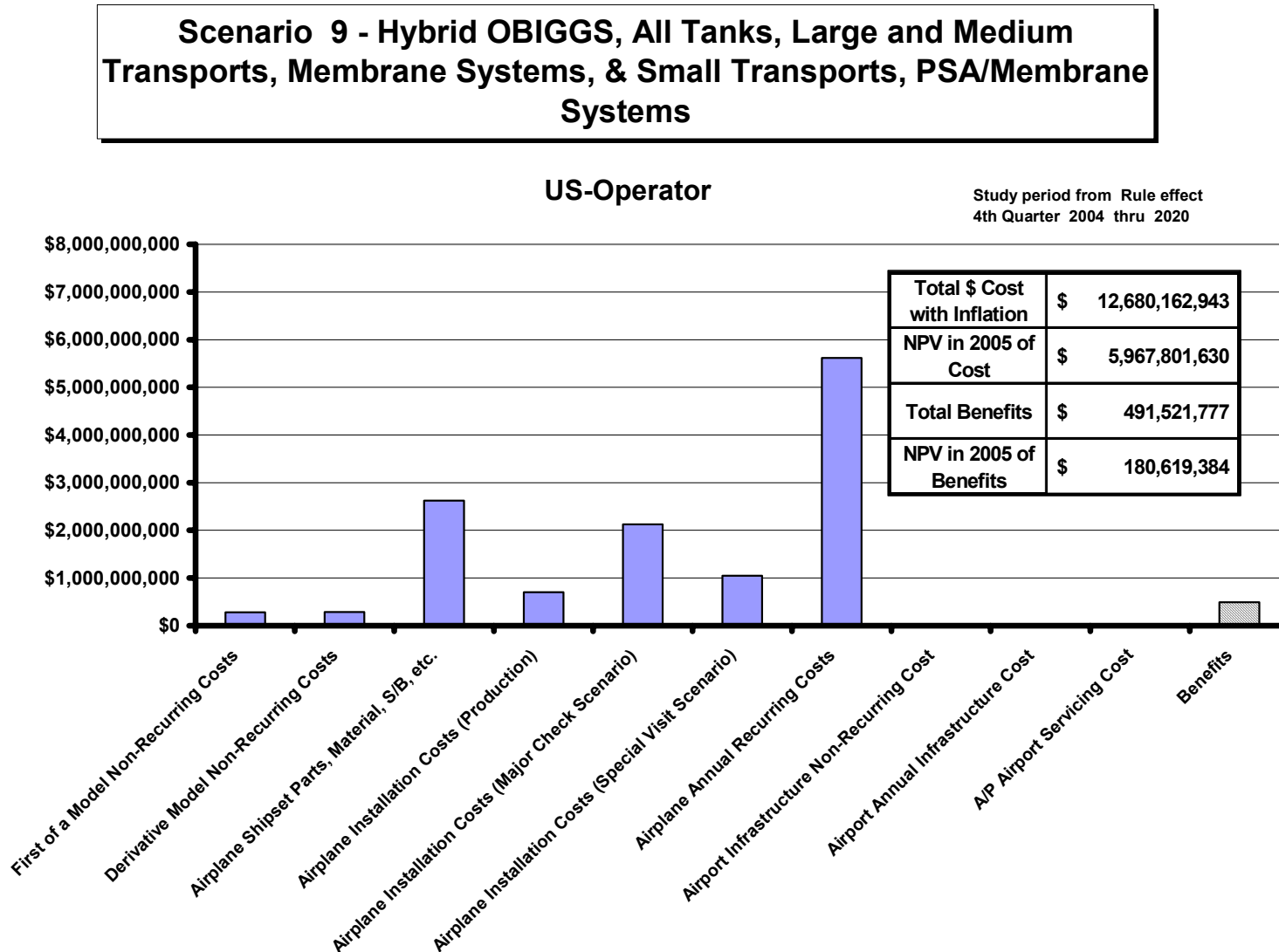


Figure G-43. Scenario 9—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S.)

**Scenario 11 - Ground Based Inerting HCWT only, All Transports**

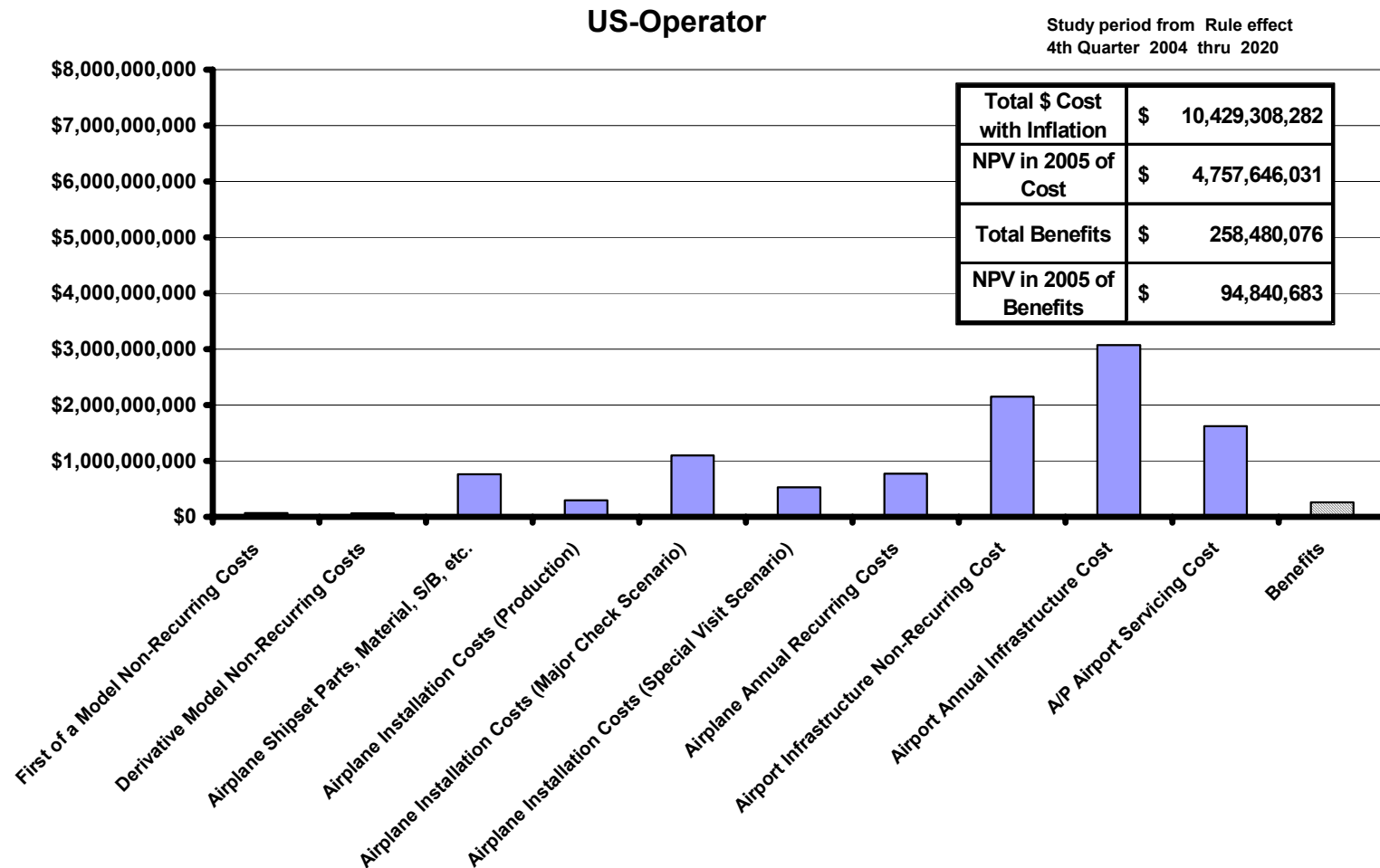


Figure G-44. Scenario 11—Ground-Based Inerting, HCWT Only, All Transports (U.S.)

## Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports

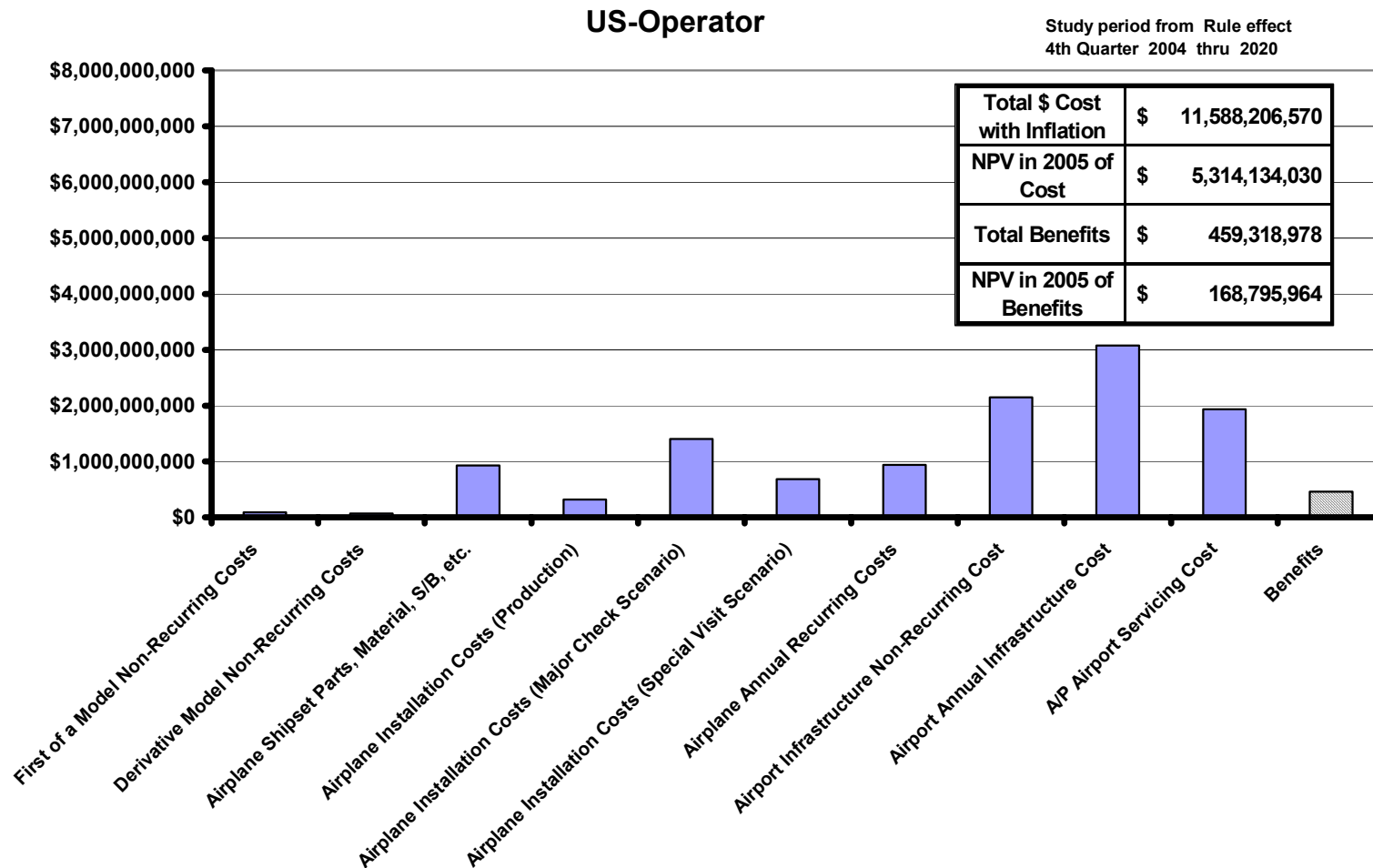


Figure G-45. Scenario 12—Ground-Based Inerting, All Fuselage Tanks, All Transports (U.S.)

**Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

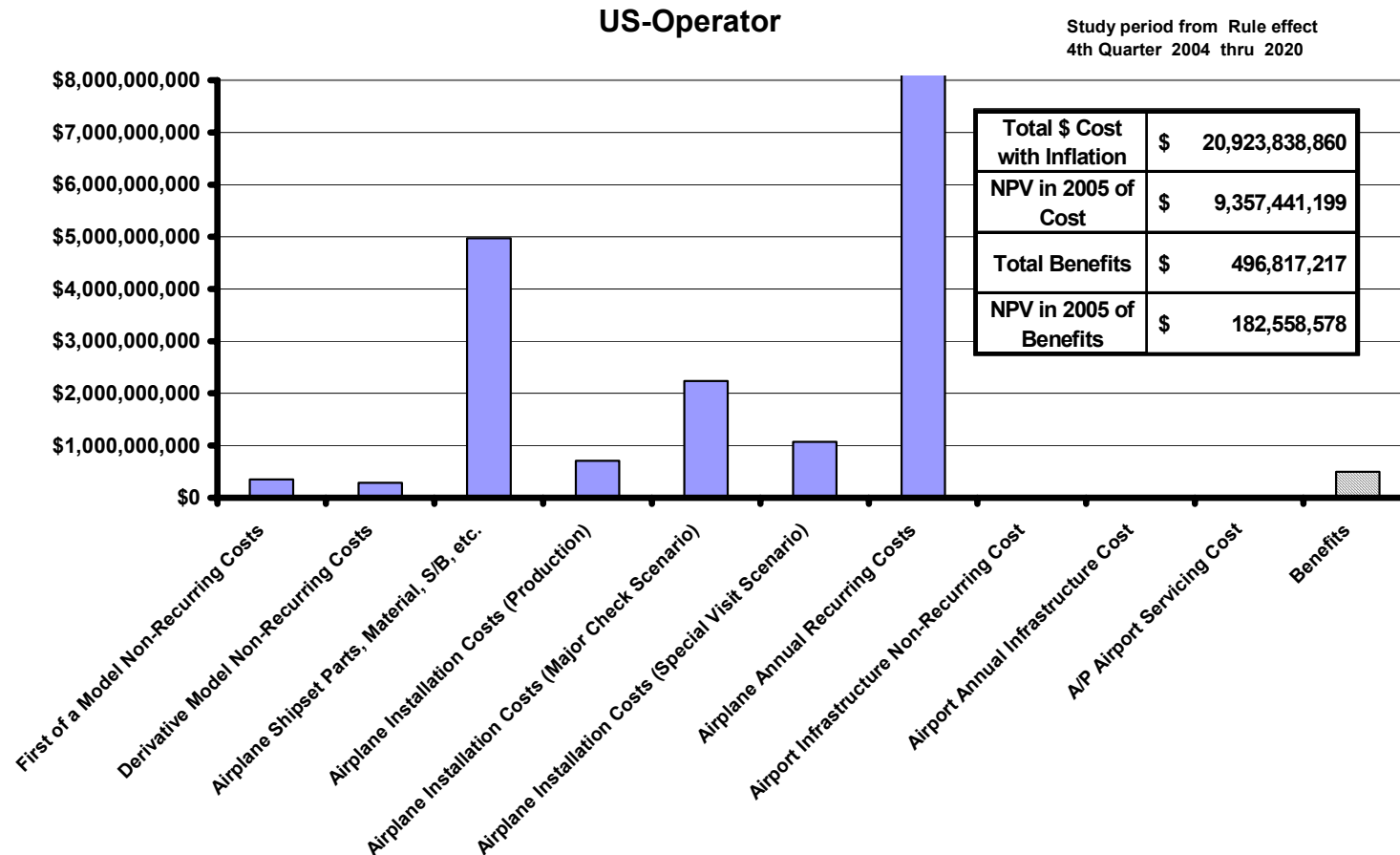


Figure G-46. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S.)

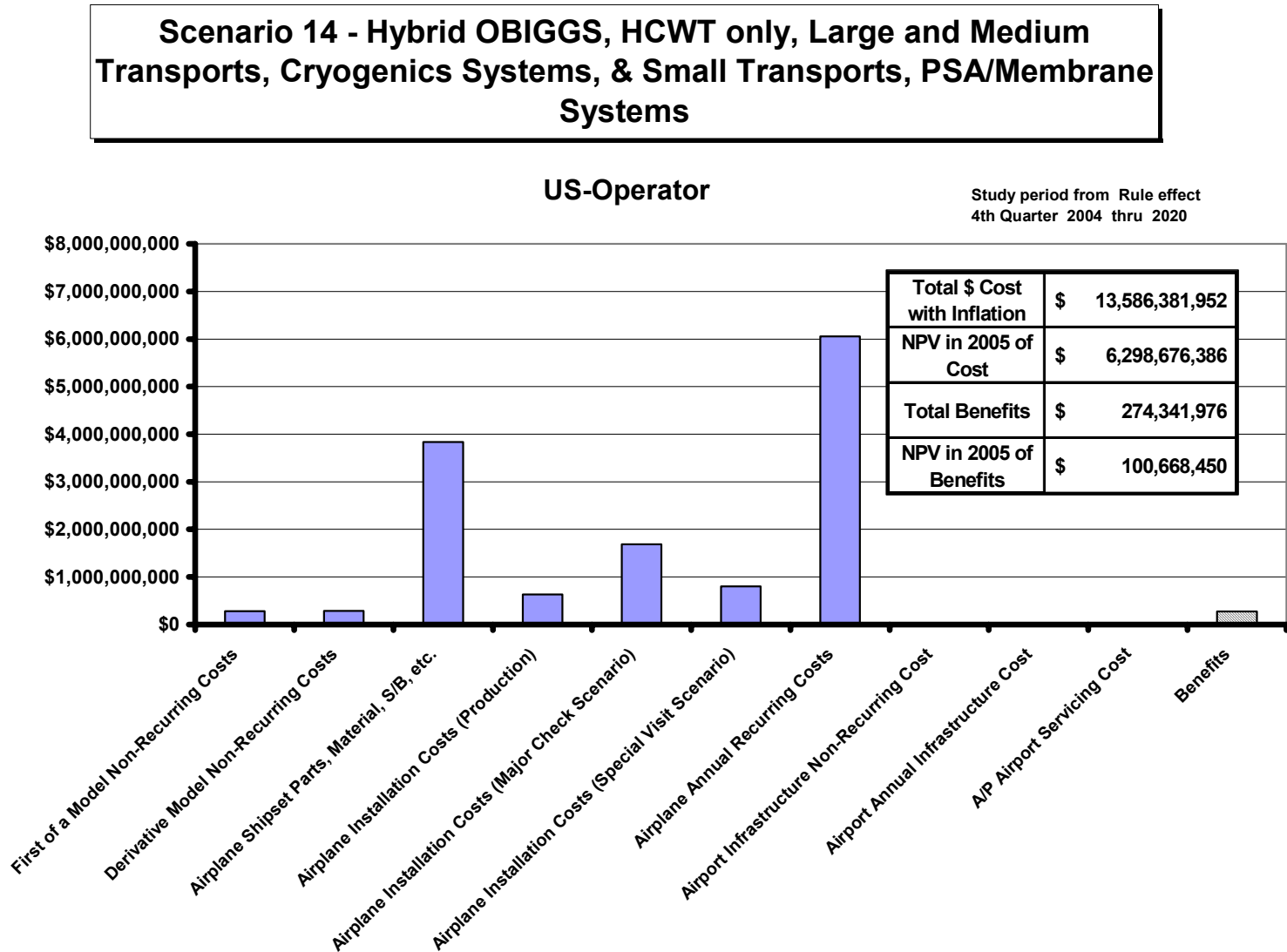


Figure G-47. Scenario 14—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S.)

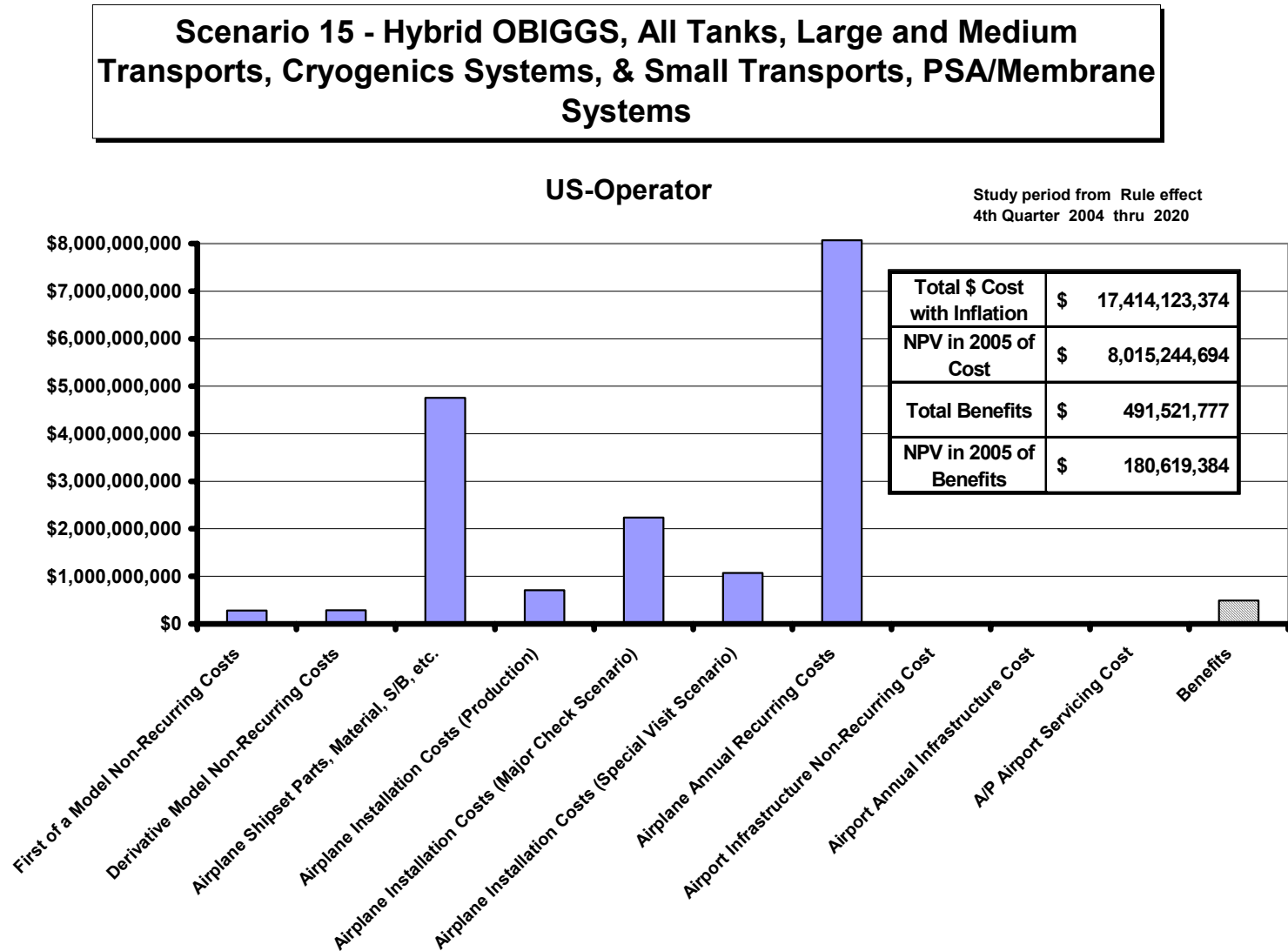


Figure G-48. Scenario 15—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S.)

## Scenario 16 - On-Board Liquid Nitrogen Inerting

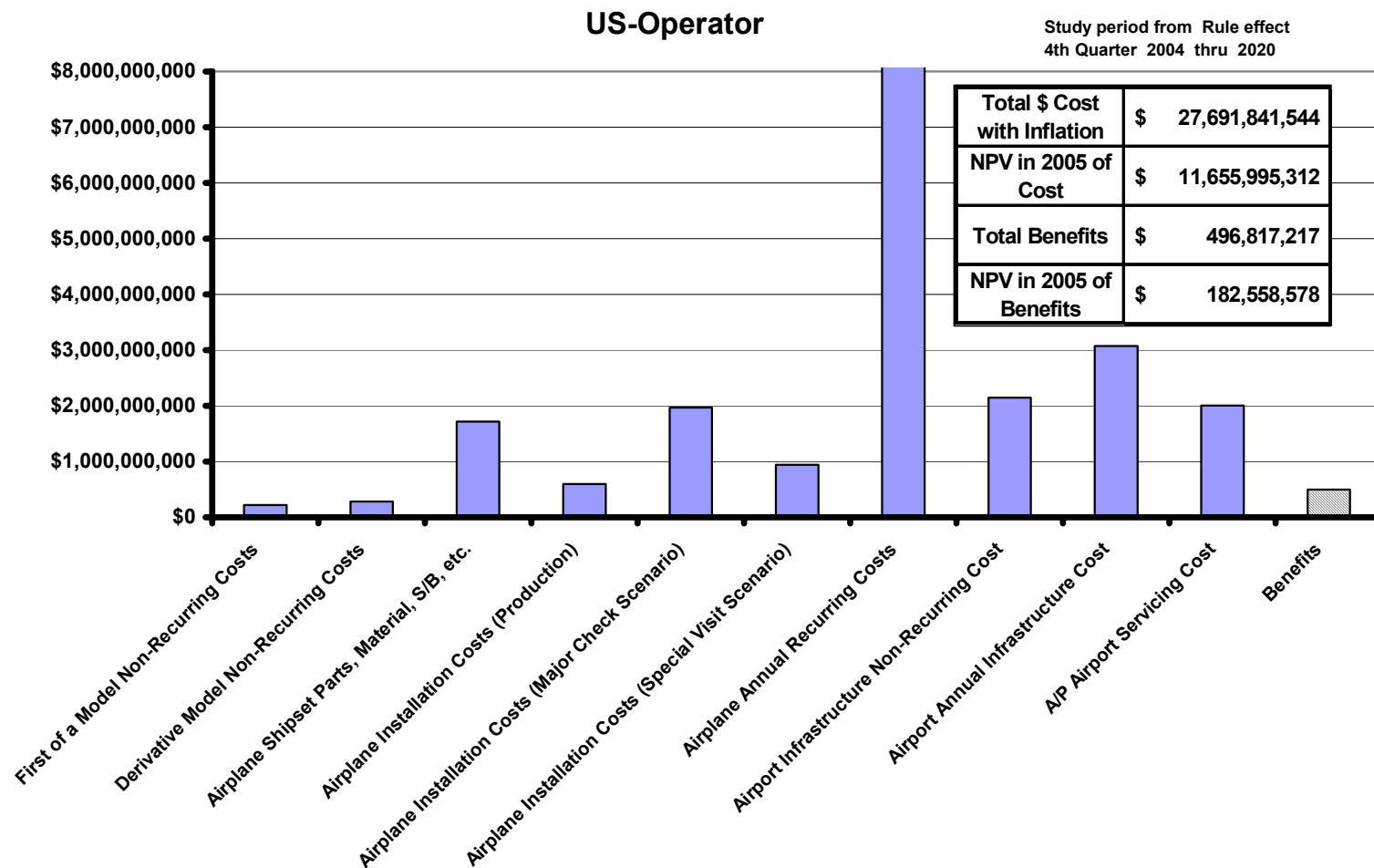


Figure G-49. Scenario 16—Onboard Liquid Nitrogen Inerting (U.S.)

Summary of Inerting Scenario Results

US-Operator - PAX Only

Values in Millions

	Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 2 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 4 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA Membrane Systems	Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 6 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 8 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 9 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA Membrane Systems	Scenario 10 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 11 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 12 - Ground Based Inerting HCWT only, All Tanks, All Transports	Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA Membrane Systems	Scenario 16 - On-Board Liquid Nitrogen Inerting
Total \$ Cost with Inflation	7,588	10,898	7,352	10,149	11,675	6,349	9,194	9,321	10,207	14,550	9,868	12,474	19,817	-	-	-
NPV in 2005 of Cost	3,768	5,215	3,678	4,896	5,491	3,166	4,442	4,246	4,672	6,698	4,692	5,884	8,598	-	-	-
Total Benefits	233	434	231	432	497	274	492	258	459	497	274	492	497	-	-	-
NPV in 2005 of Benefits	86	159	85	159	183	101	181	95	169	183	101	181	183	-	-	-

Figure G-50. Cost Summary of U.S. Fleet, Passenger Only

**Scenario 1 - On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

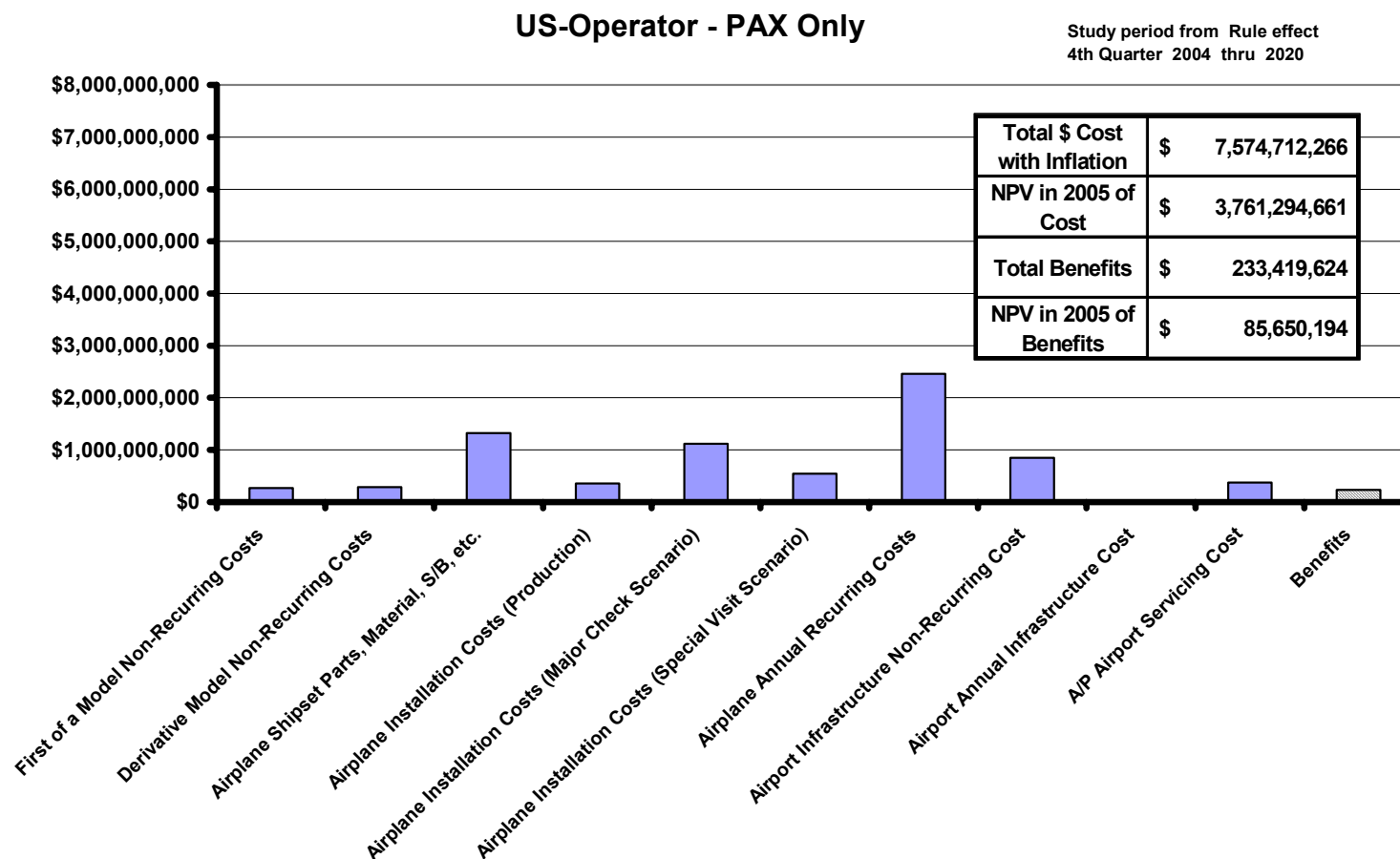


Figure G-51. Scenario 1—Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 2 - On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

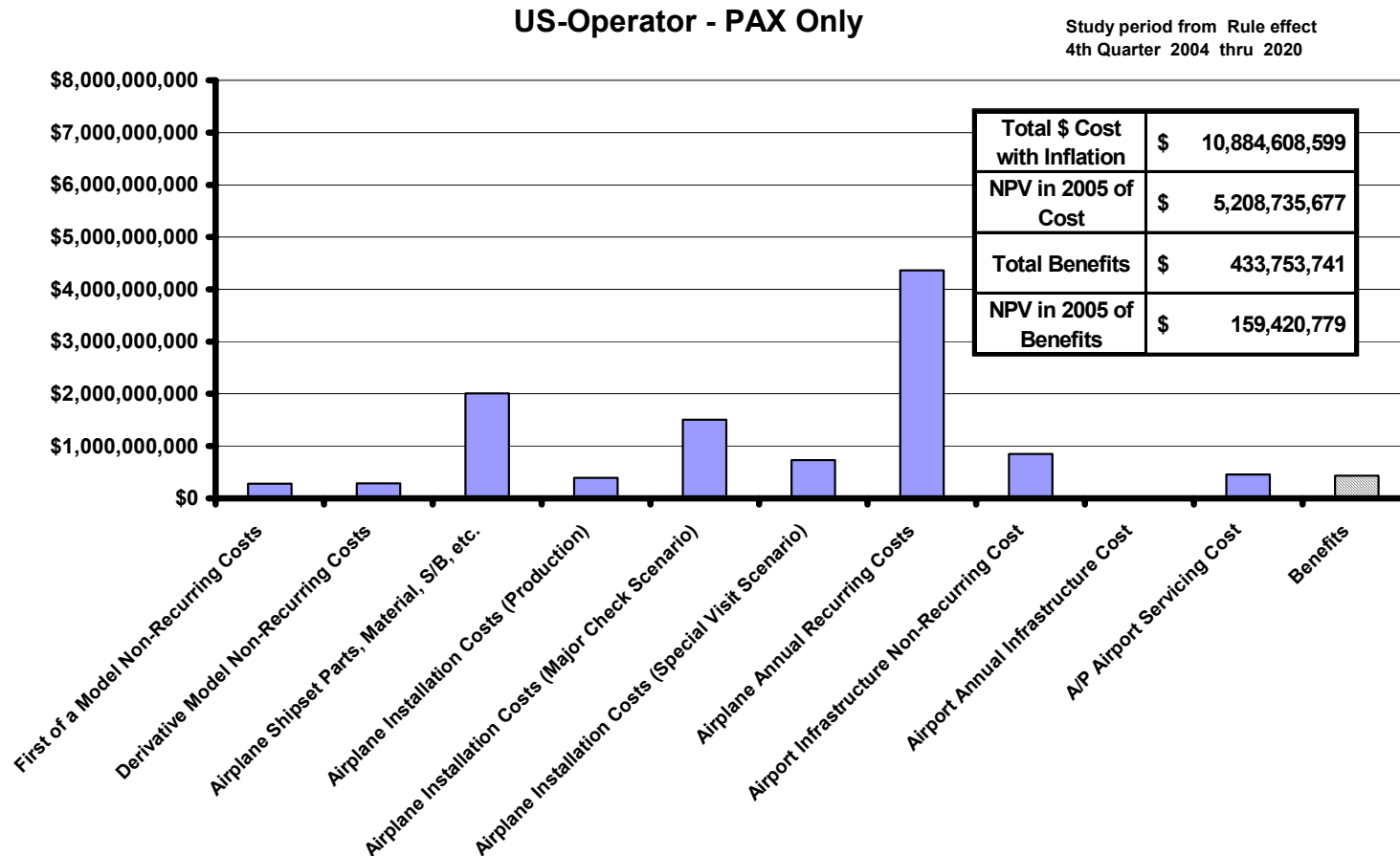


Figure G-52. Scenario 2—Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 3 - Hybrid On-Board Ground Inerting HCWT only, Large, Medium, Small Transports, PSA/Membrane Systems**

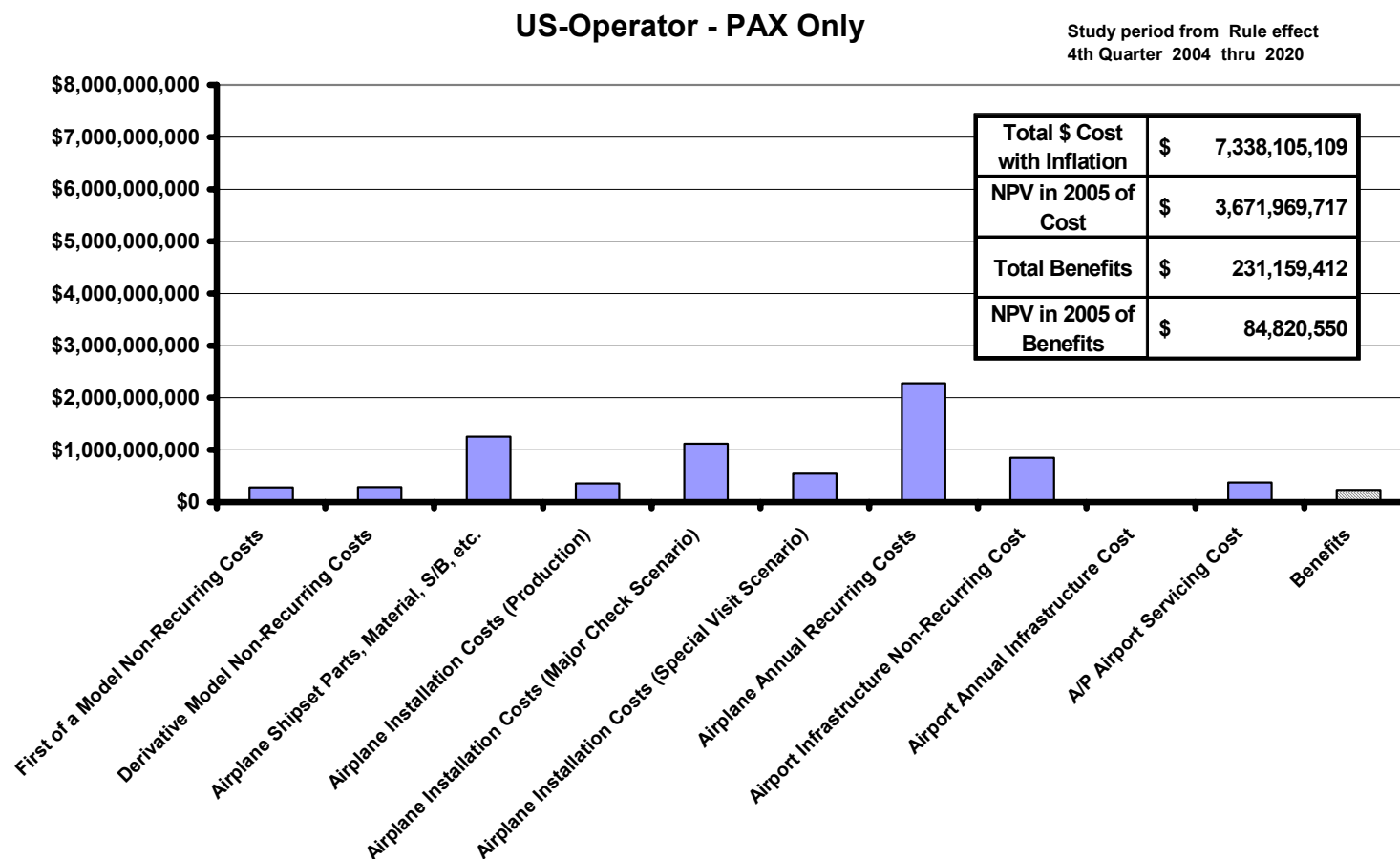


Figure G-53. Scenario 3—Hybrid Onboard Ground Inerting, HCWT Only, Large, Medium, Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 4 - Hybrid On-Board Ground Inerting All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems**

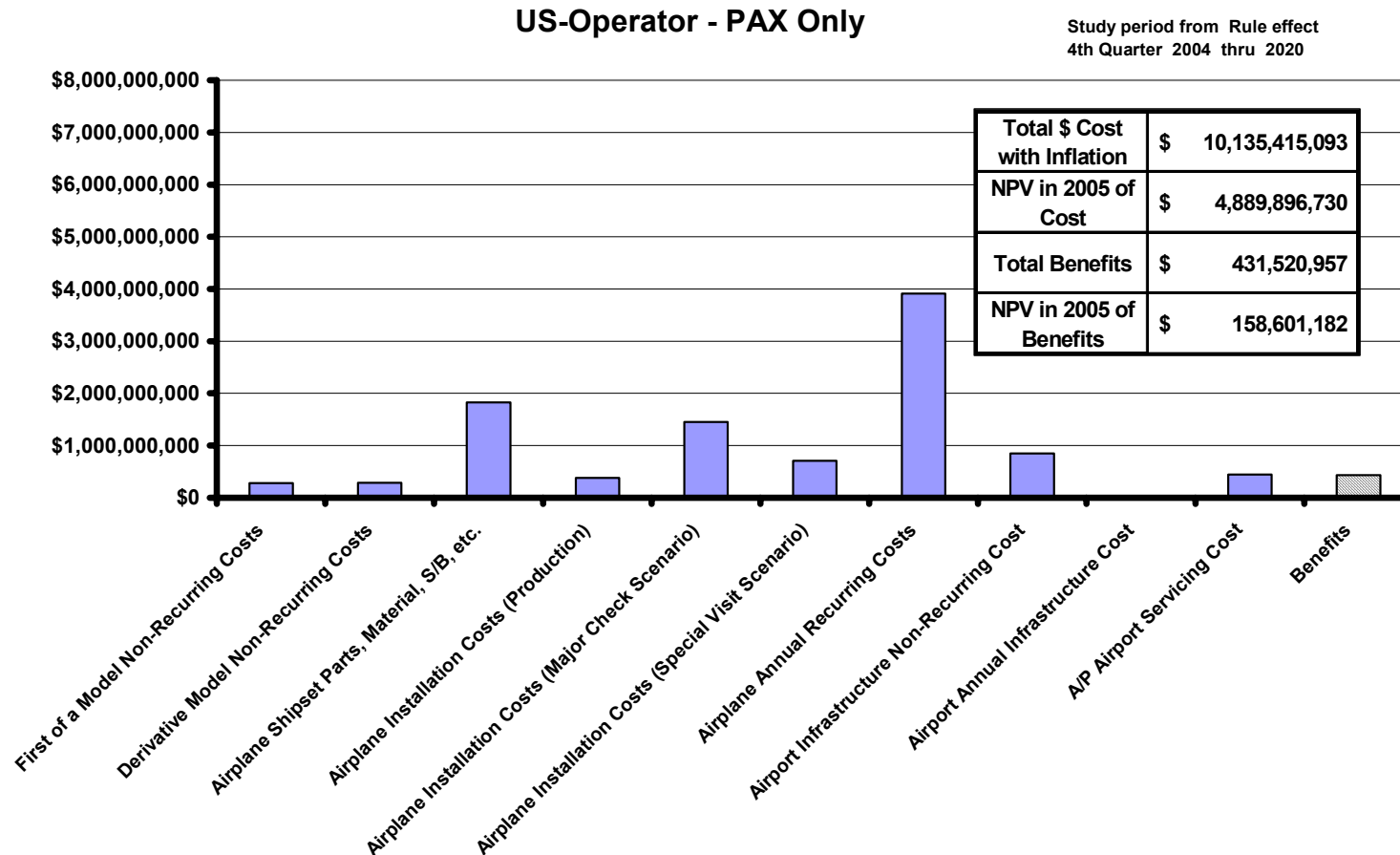


Figure G-54. Scenario 4—Hybrid Onboard Ground Inerting, All Fuselage Tanks, Large, Medium, Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 5 - OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

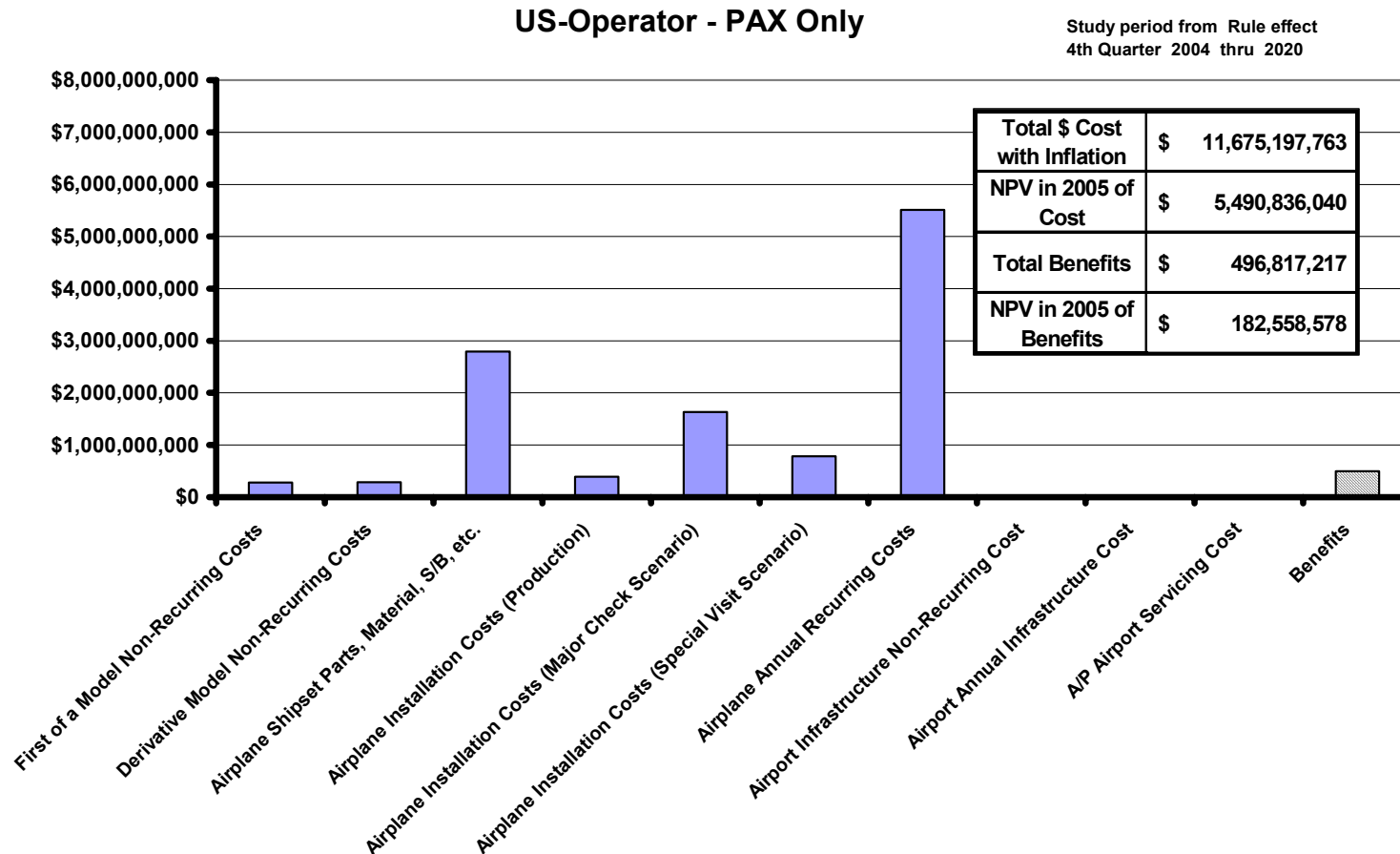


Figure G-55. Scenario 5—OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 7 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Membrane Systems, & Small Transports, PSA/Membrane Systems**

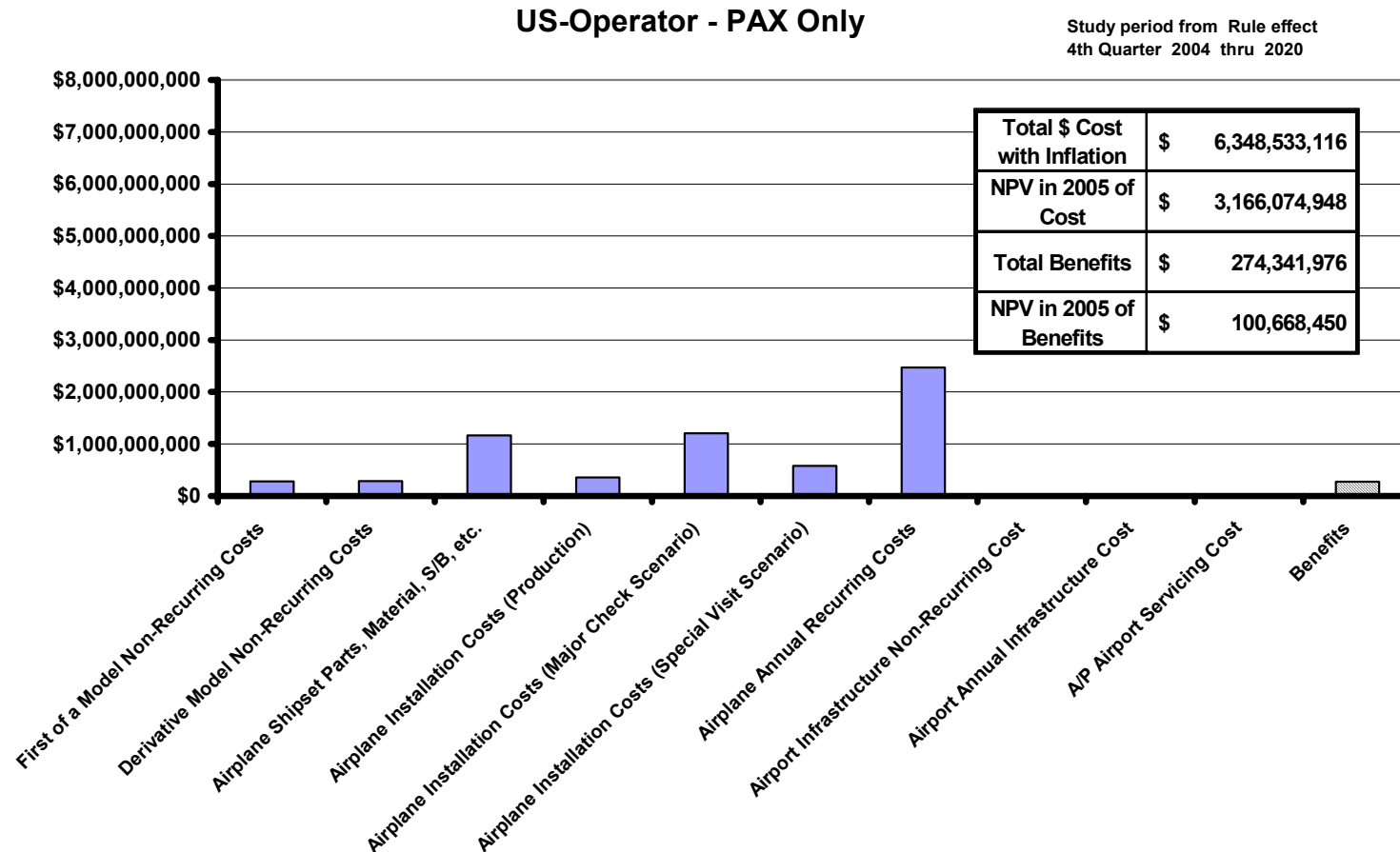


Figure G-56. Scenario 7—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

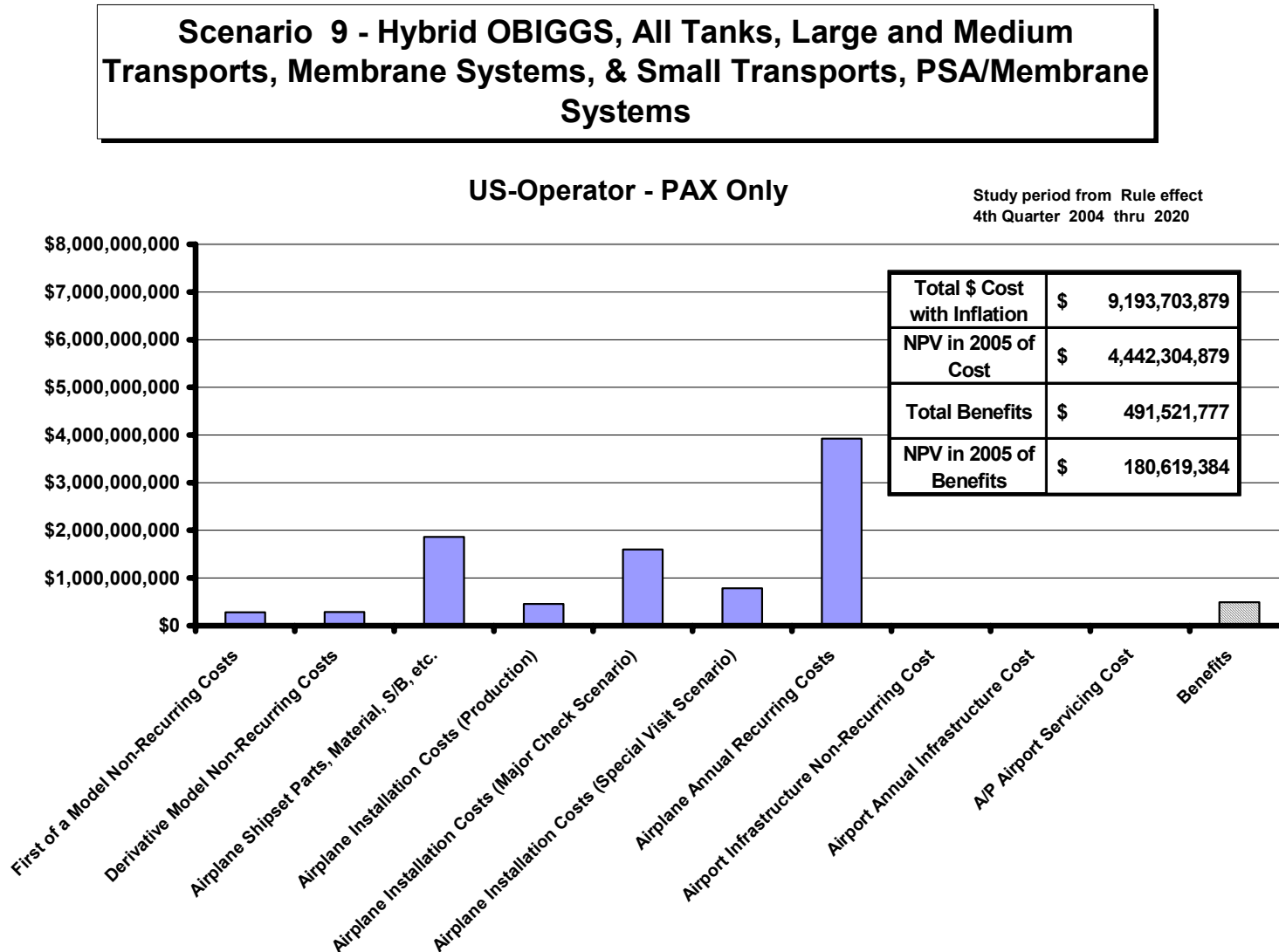


Figure G-57. Scenario 9—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Membrane Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 11 - Ground Based Inerting HCWT only, All Transports**

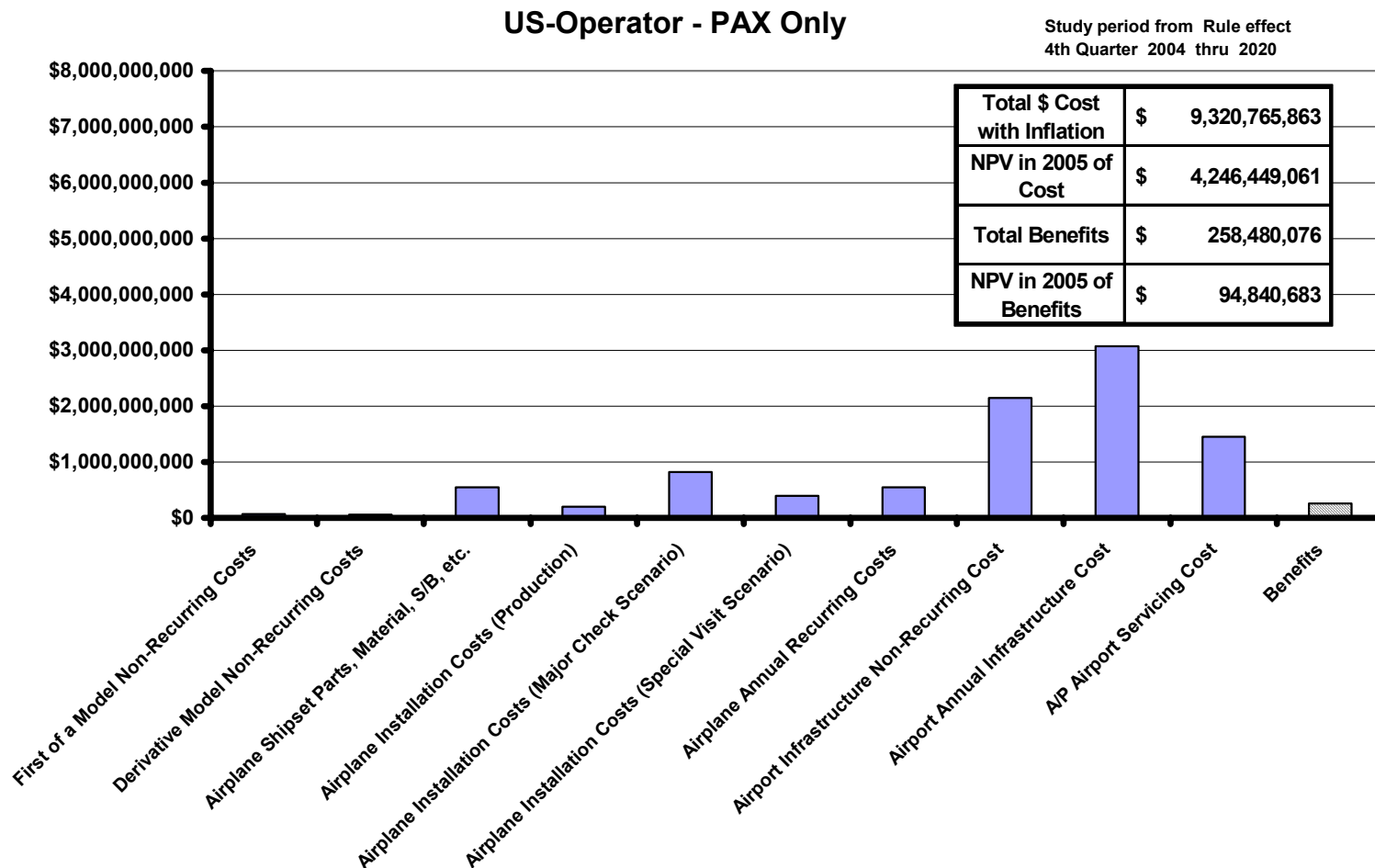


Figure G-58. Scenario 11—Ground-Based Inerting, HCWT Only, All Transports (U.S., Passenger Only)

## Scenario 12 - Ground Based Inerting All Fuselage Tanks, All Transports

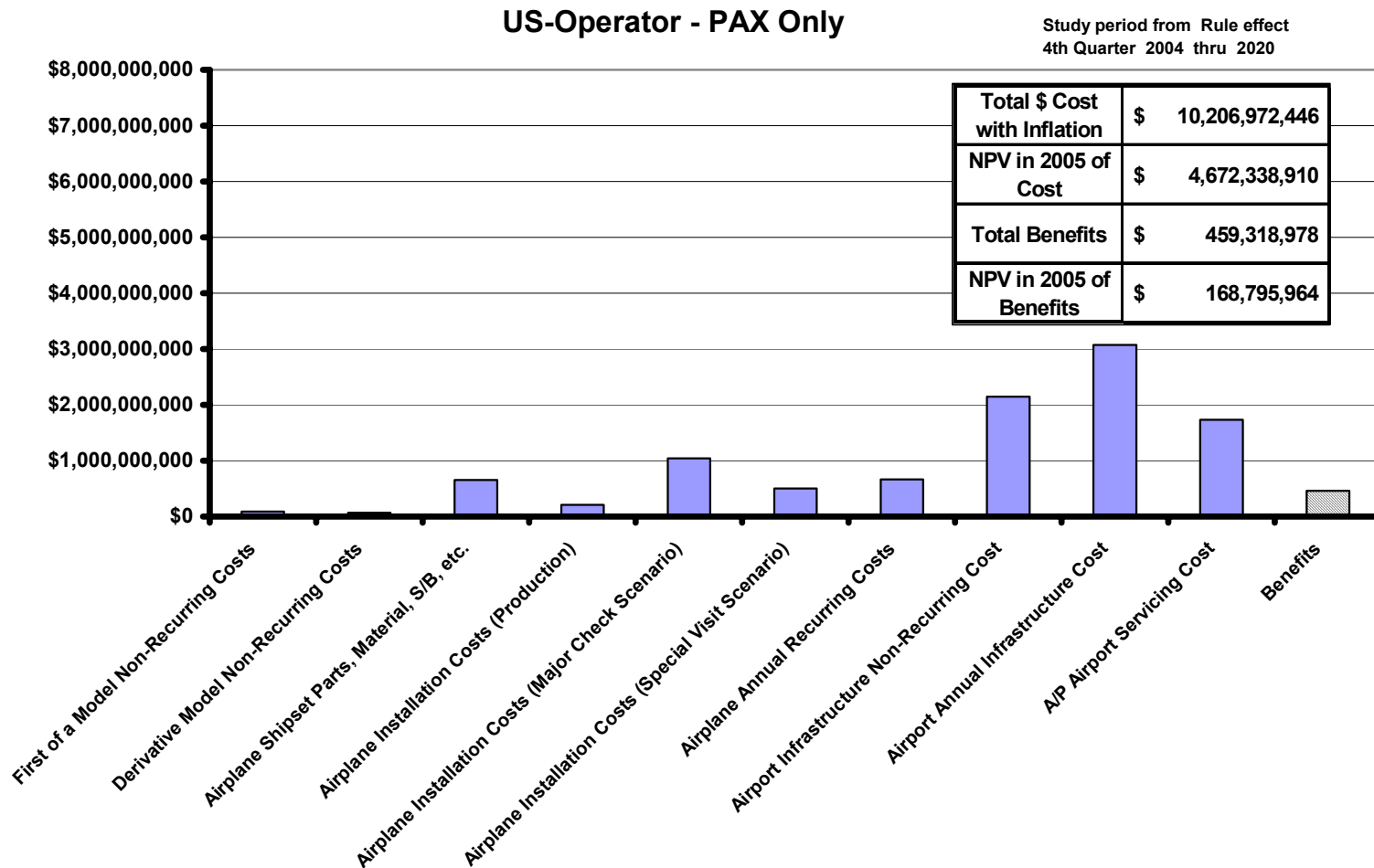


Figure G-59. Scenario 12—Ground-Based Inerting, All Fuselage Tanks, All Transports (U.S., Passenger Only)

**Scenario 13 - OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

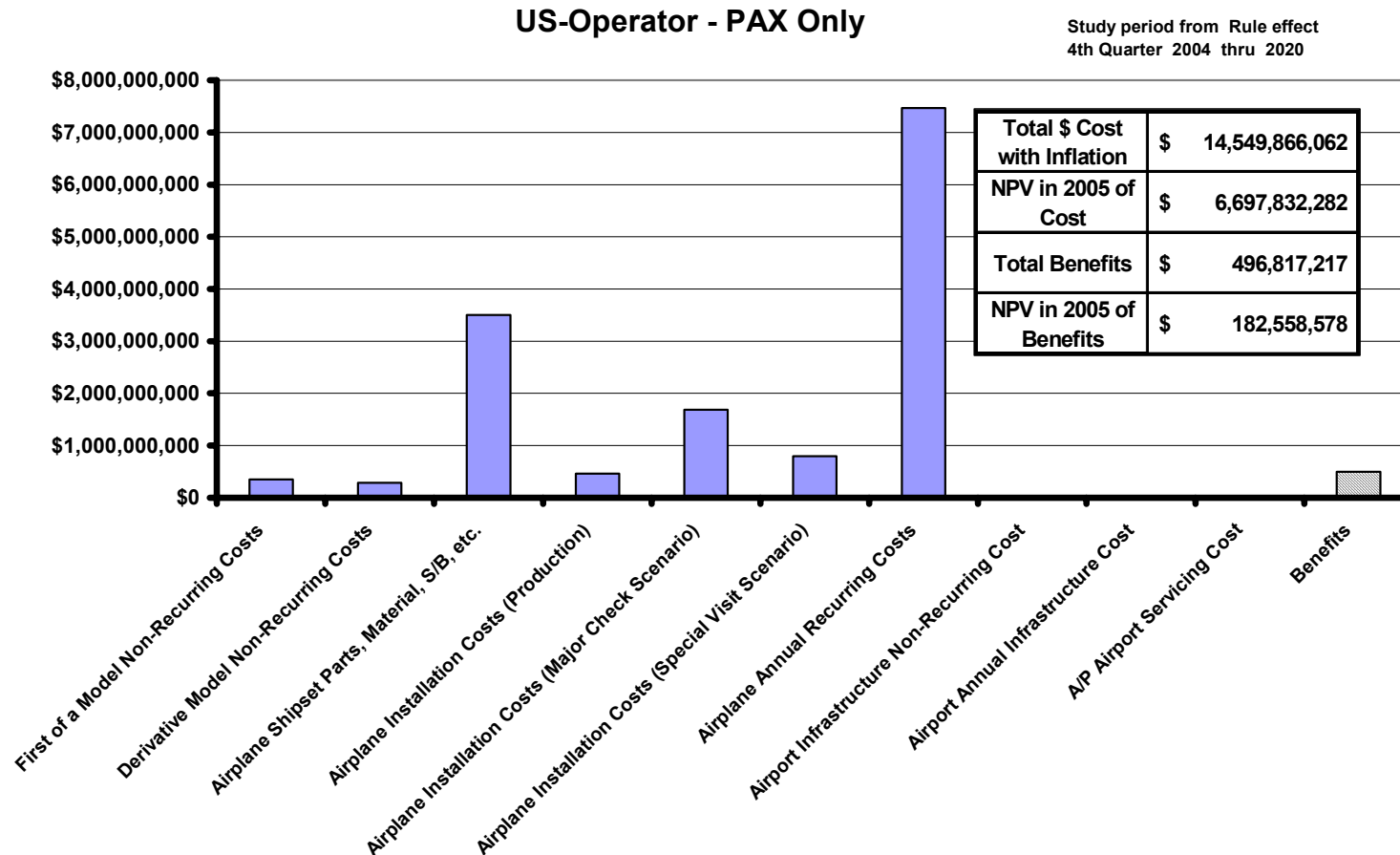


Figure G-60. Scenario 13—OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 14 - Hybrid OBIGGS, HCWT only, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

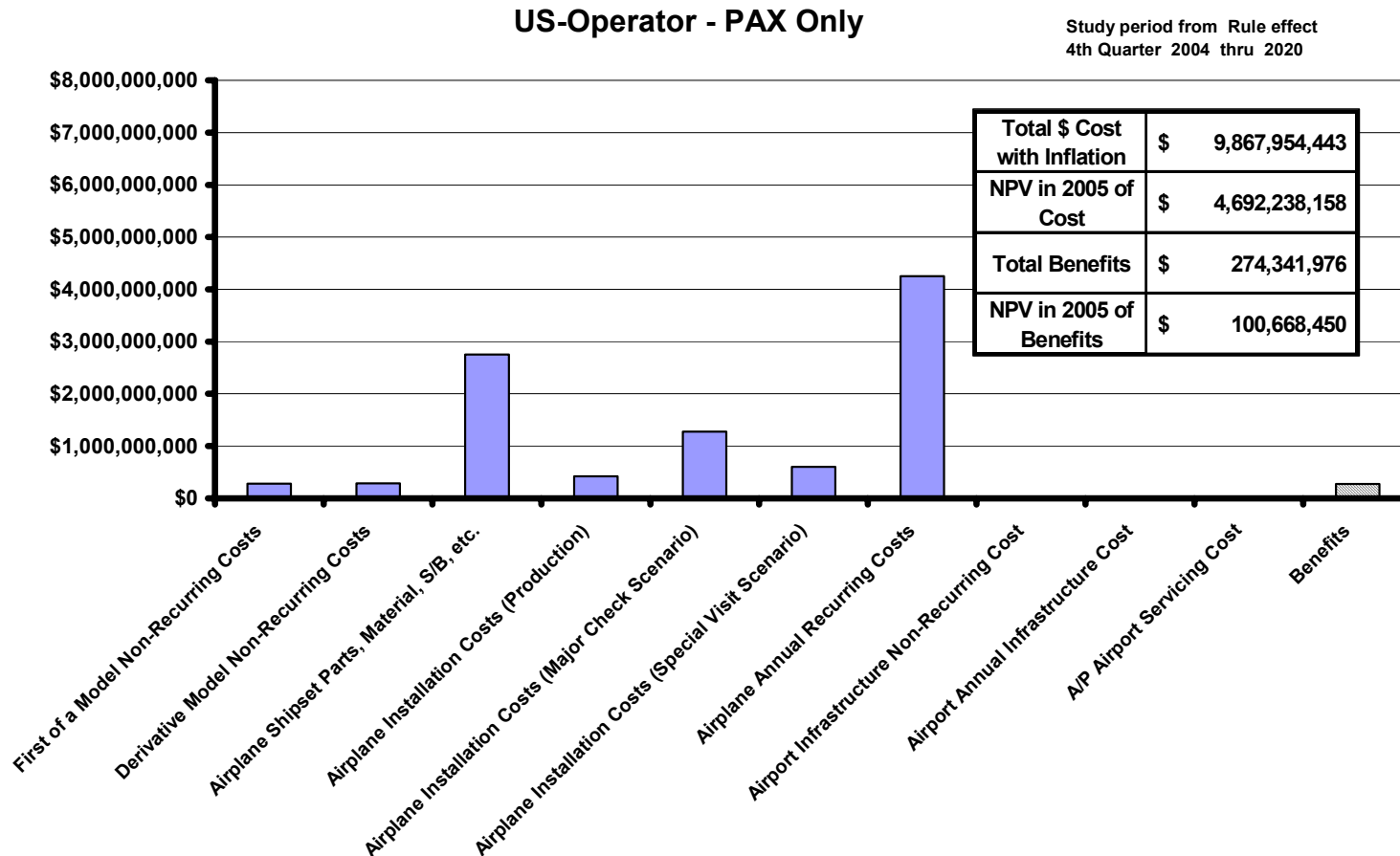


Figure G-61. Scenario 14—Hybrid OBIGGS, HCWT Only, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

**Scenario 15 - Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenics Systems, & Small Transports, PSA/Membrane Systems**

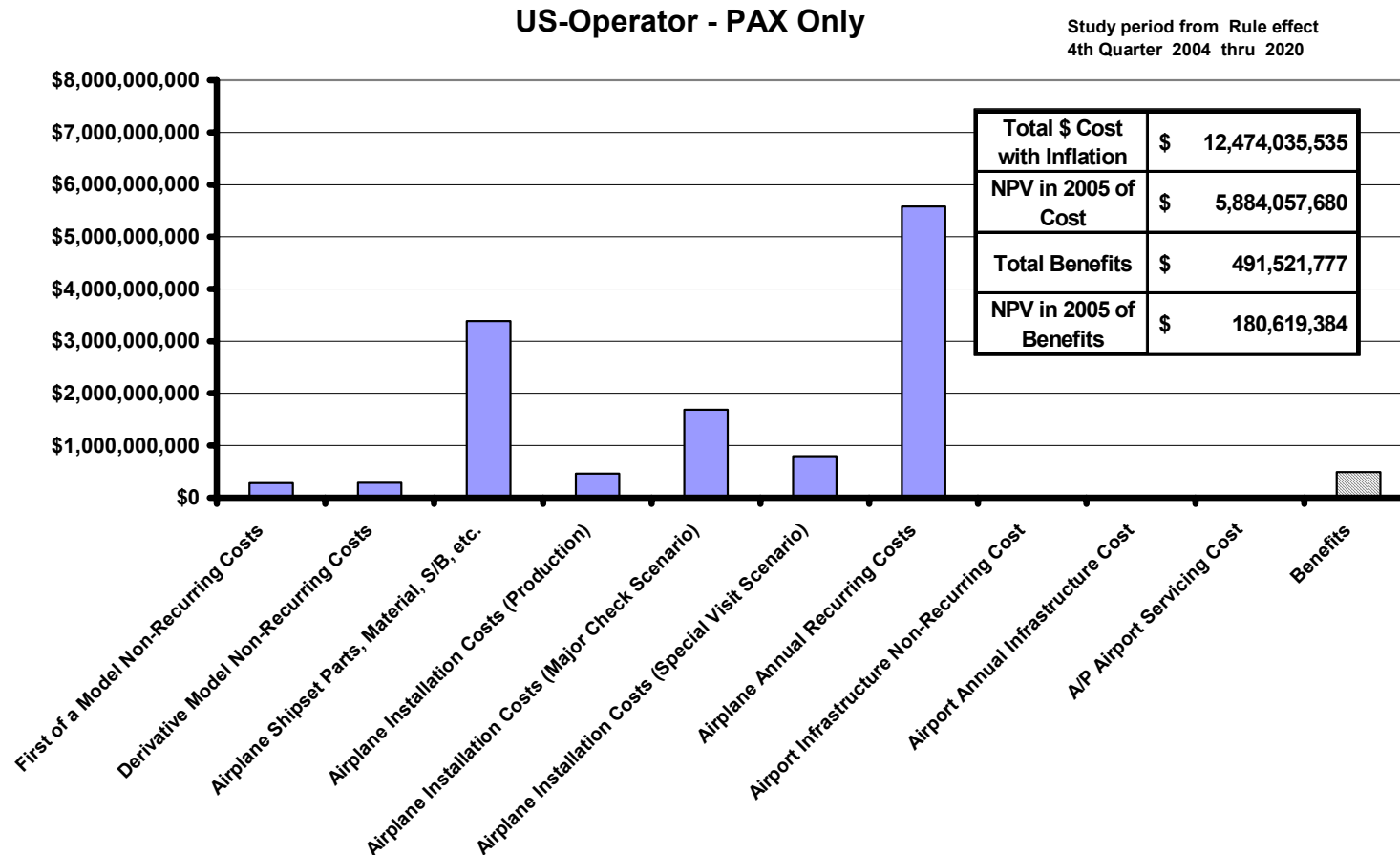


Figure G-62. Scenario 15—Hybrid OBIGGS, All Tanks, Large and Medium Transports, Cryogenic Systems, and Small Transports, PSA/Membrane Systems (U.S., Passenger Only)

## Scenario 16 - On-Board Liquid Nitrogen Inerting

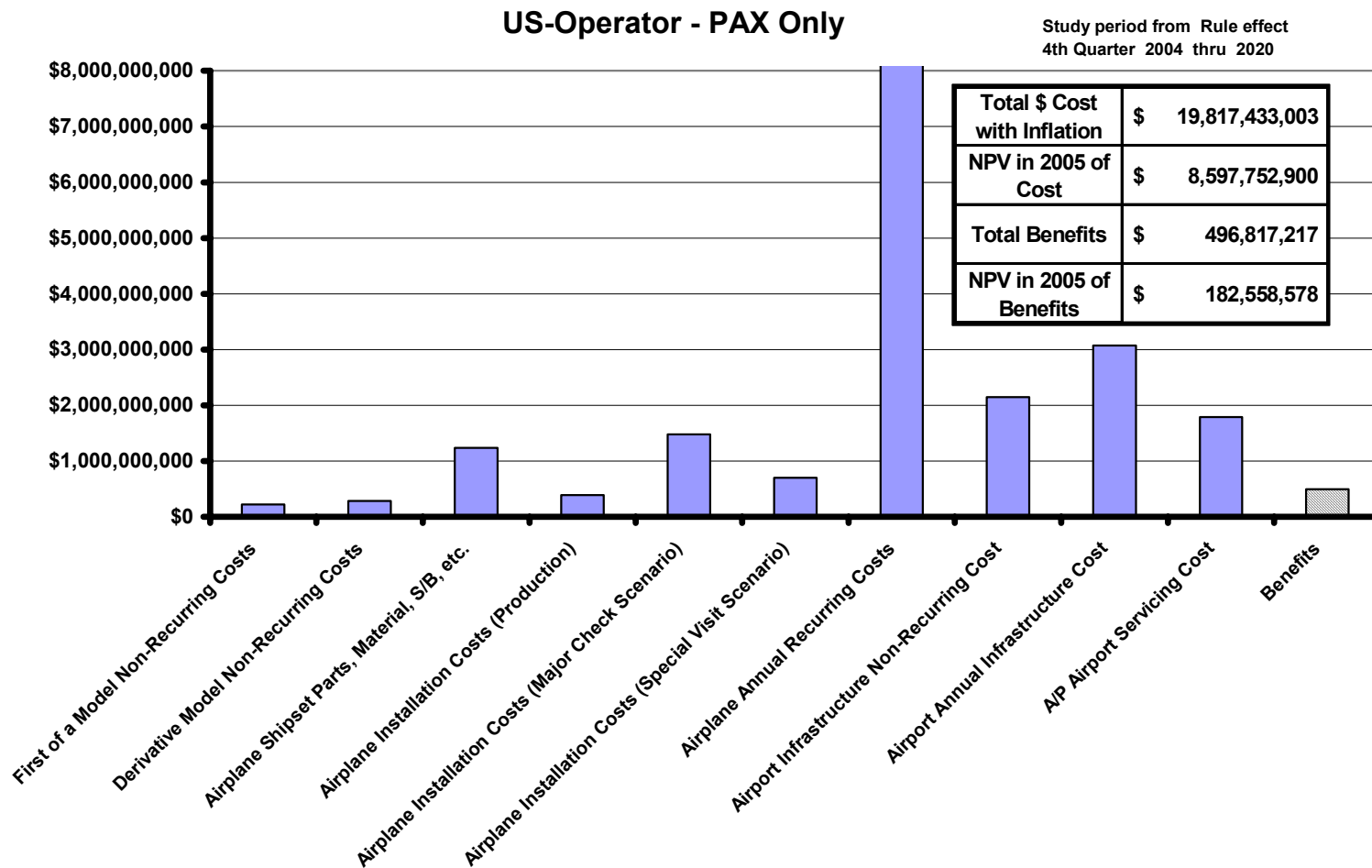


Figure G-63. Scenario 16—Onboard Liquid Nitrogen Inerting (U.S. Fleet, Passenger Only)

### **3.0 GASEOUS VERSUS LIQUID NITROGEN**

The first 15 scenarios evaluated in this study feature gaseous nitrogen systems. The 16th scenario features a liquid nitrogen system. This ARAC study focused on gaseous nitrogen generating systems rather than stored liquid nitrogen systems because gas generating systems are less expensive and less hazardous. The early inerting systems, such as that aboard the Lockheed C-5 Galaxy military transport, used stored liquid nitrogen. Those systems were heavy and relied on a large ground-support system. As technology has advanced, onboard gas-generating inerting systems like OBIGGS have become more practical. The system weight and inlet airflow and pressure to volume of nitrogen produced has vastly improved. All of the recently designed and installed nitrogen inerting systems on military aircraft have been of the OBIGGS type. A brief cost analysis of the liquid nitrogen (LN<sub>2</sub>) system is included to provide a comparison of costs relative to the other inerting systems. The safety benefits of the LN<sub>2</sub> system are assumed to be similar to OBIGGS.

The main advantage of a stored liquid nitrogen system is that it does not require aircraft bleed air or significant aircraft power to operate. However, such systems incur penalties that include higher weight than for air separation (i.e., gas generation) technology, on-board system complexity, and the need for a ground-based nitrogen supply system. The computed LN<sub>2</sub> weight is based on carrying enough LN<sub>2</sub> for three flights. The amount assumed carried reflects a proposal for a closed-loop control system that minimizes the amount of LN<sub>2</sub> required. As proposed, this system relies on oxygen sensing in the fuel tank and a control system that releases enough LN<sub>2</sub> to keep the tank inert. Ideally, this system would require only enough N<sub>2</sub> to fill the ullage once per flight.

The system described above has been sized to inert all fuel tanks on the airplane. The oxygen sensing and control system has not yet been demonstrated on a commercial airplane. The weights presented in figure G-64 are based on the FAA study "Performance of a DC-9 Aircraft Liquid Nitrogen Fuel Tank Inerting System," published in 1972.

	Large airplane	Medium airplane	Small airplane
LN <sub>2</sub> weight (lb)	1,282	570	119
Storage, plumbing, controls, etc., weight (lb)	1,770	786	164
Total weight (lb)	3,052	1,356	283

*Figure G-64. Liquid Nitrogen System Weight*

Liquid nitrogen systems require the cryogenic transport and storage of nitrogen in liquid form, which boils at -195°C or -315°F. Transport, storage, and handling of LN<sub>2</sub> requires precautions to prevent severe skin burns on contact. Also, a broken bottle or distribution line may rapidly flood an enclosed area with nitrogen, causing asphyxiation. Because of the dangers and hazards associated with handling LN<sub>2</sub>, it was assumed that a mechanic, and not ground service workers, would be required to fill the airplane storage tanks.

It was assumed that the LN<sub>2</sub> would be generated and stored at each airport, so the LN<sub>2</sub> cost is the same as the gaseous N<sub>2</sub> costs. Although the airplane would be serviced once for every three flights, the cost of the labor is three times higher because it requires a mechanic instead of ground service workers. Consequently, the ground servicing costs would be about the same as for the GBI system.

It was assumed that the design, development, certification, and implementation costs for the LN<sub>2</sub> system are similar to the other systems evaluated in this study. The cost analysis for the LN<sub>2</sub> system includes only the large, medium and small airplanes. The total cost over the 16-year study period includes the initial airplane and airport modification costs and the accumulated annual recurring costs. Airplane nonrecurring costs include engineering design for the modifications and additions to fuel system components, interfaces, instruments or displays, relocation of other equipment, wiring, tubing or ducting, and avionics software or modules. The nonrecurring engineering costs also include changes to documents (e.g., Specs, ICDs); manuals (e.g., AFM, Opts, MM); production change records; laboratory, ground, and flight tests; and FAA/JAA certification. The costs also include major-supplier parts and assemblies, tubing, wiring,

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ducting, Service Bulletin and kitting costs (retrofit), and special tooling for installation. These costs were based on the costs of the GBI airplane system with the addition of an LN<sub>2</sub> storage tank and an oxygen sensing and control system. The airline recurring and nonrecurring costs were based on the installation and operating costs of an onboard system. Although the closed-loop oxygen sensing system is more complex than an OBIGGS, it was assumed the maintenance and delay costs would be similar.



Appendix H

Safety Analysis Task Team Final Report

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